High Maturity!
How Do We Know?

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Outline

Overview

Watts Humphrey asserted as early as 1988:

> ***"I can walk into an organization, speak to a few members of a project, and know within 10 minutes the maturity level of the organization."***

A series of analyses of SEI assessment data conducted in 1989-1990 by Manuel Lombardero and Alyson Gabbard Wilson supports this.

- **Derived simple binary decision trees that estimated an organization's maturity level (ML 1-3) with low rates of both false positives and false negatives**
- **CART (Correlation and Regression Tree Analysis)**

Fundamental Axioms of Statistical Thinking

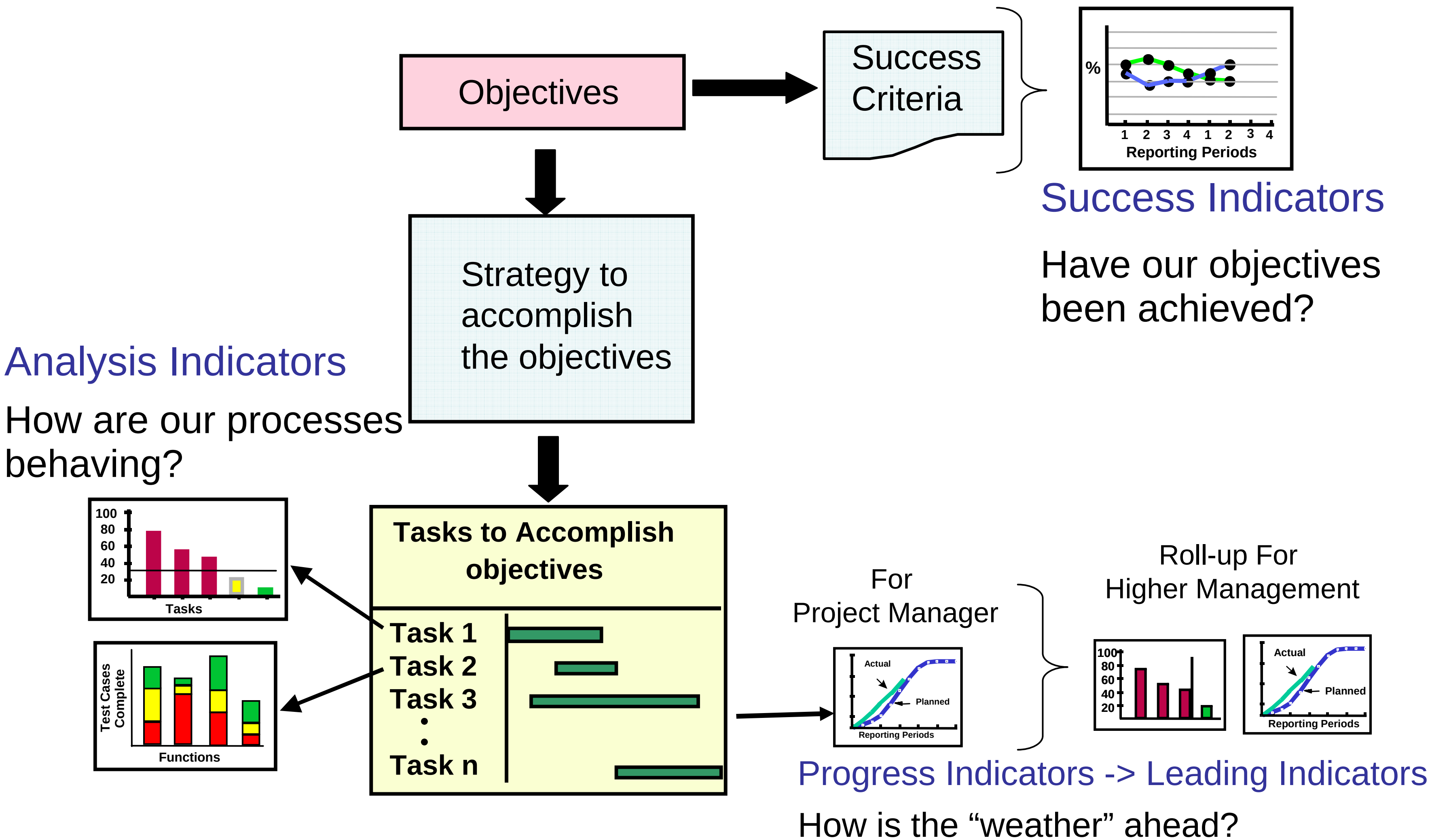
All product development and services are a series of interconnected processes.

All processes are variable.

Understanding variation is the basis for management by fact and systematic improvement:

- understand the past–quantitatively
- control the present–quantitatively
- predict the future–quantitatively

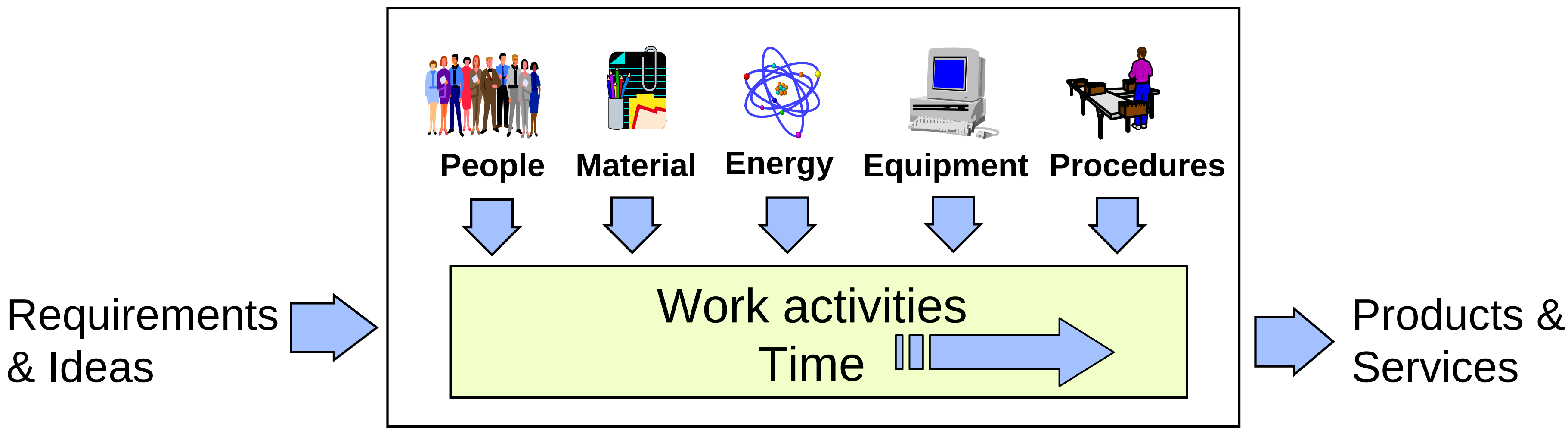
Improvement Must be for the Business



What Is a Process in Relation to Products and Services?

Processes defined in CMMI are “activities that can be recognized as implementations of practices in a CMMI model.”

They may also be thought of as a system of causes that includes the people, materials, energy, equipment, and procedures necessary to produce a product or service.

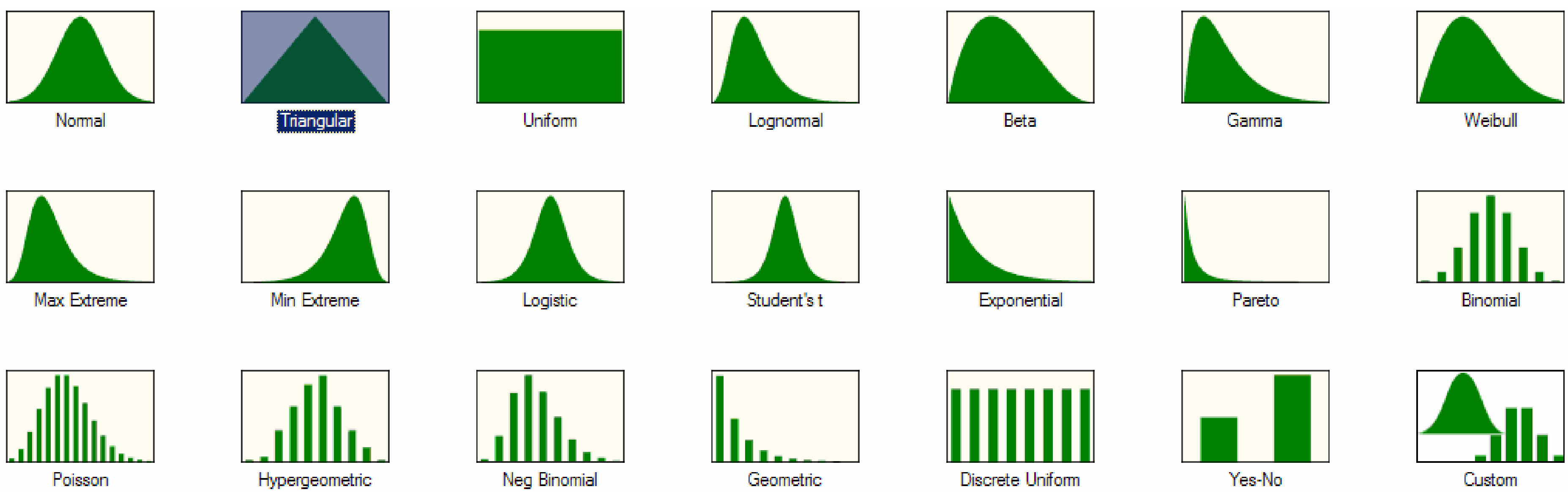


Distributions Describe Variation

Populations of data are characterized as distributions in most statistical procedures:

- expressed as an "assumption" for the procedure
- can be represented using an equation

Examples of distributions you may come across:



Central Tendency and Dispersion

Central tendency implies location:

- middle of a group of values
- balance point
- examples include mean, median, and mode

Dispersion implies spread:

- distance between values
- how much the values tend to differ from one another
- examples include range and (sample) standard deviation

These two are used together to understand the baseline of a process-performance factor and/or outcome.

Sampling the Data

Sampling Considerations

- How precise do we need the answer to be?
  What is our tolerable margin of error?
- How much variation do we expect in the sample data?
  What is the sample's standard deviation or proportion percentage?
- How confident do we need to be in the results?
  What levels of "false alarms" and "escapes" are we willing to risk?

Measurement Error Threatens Statistical Analysis

How big is the measurement error?

What are the sources of measurement error?

Is the measurement system stable over time?

Is the measurement system capable?

How can the measurement system be improved?

Impacts of Poor Data Quality

Inability to conduct hypothesis tests and predictive modeling

Inability to manage the quality and performance software or application development

Ineffective process change instead of process improvement

Improper architecture and design decisions driving up the lifecycle cost and reducing the useful life of the product

Ineffective and inefficient testing causing issues with time to market, field quality, and development costs

Products that are painful and costly to use within real-life usage profiles

Bad information leads to bad decisions!

High Maturity Practices Require Process Understanding & Statistical Thinking

Real process behavior must be understood before making conclusions about the performance of products or services.

Ask these questions to find out about real process behavior:

- What is the normal or inherent process variation?
- What differentiates inherent from anomalous variation?
- What is causing the anomalous variation?

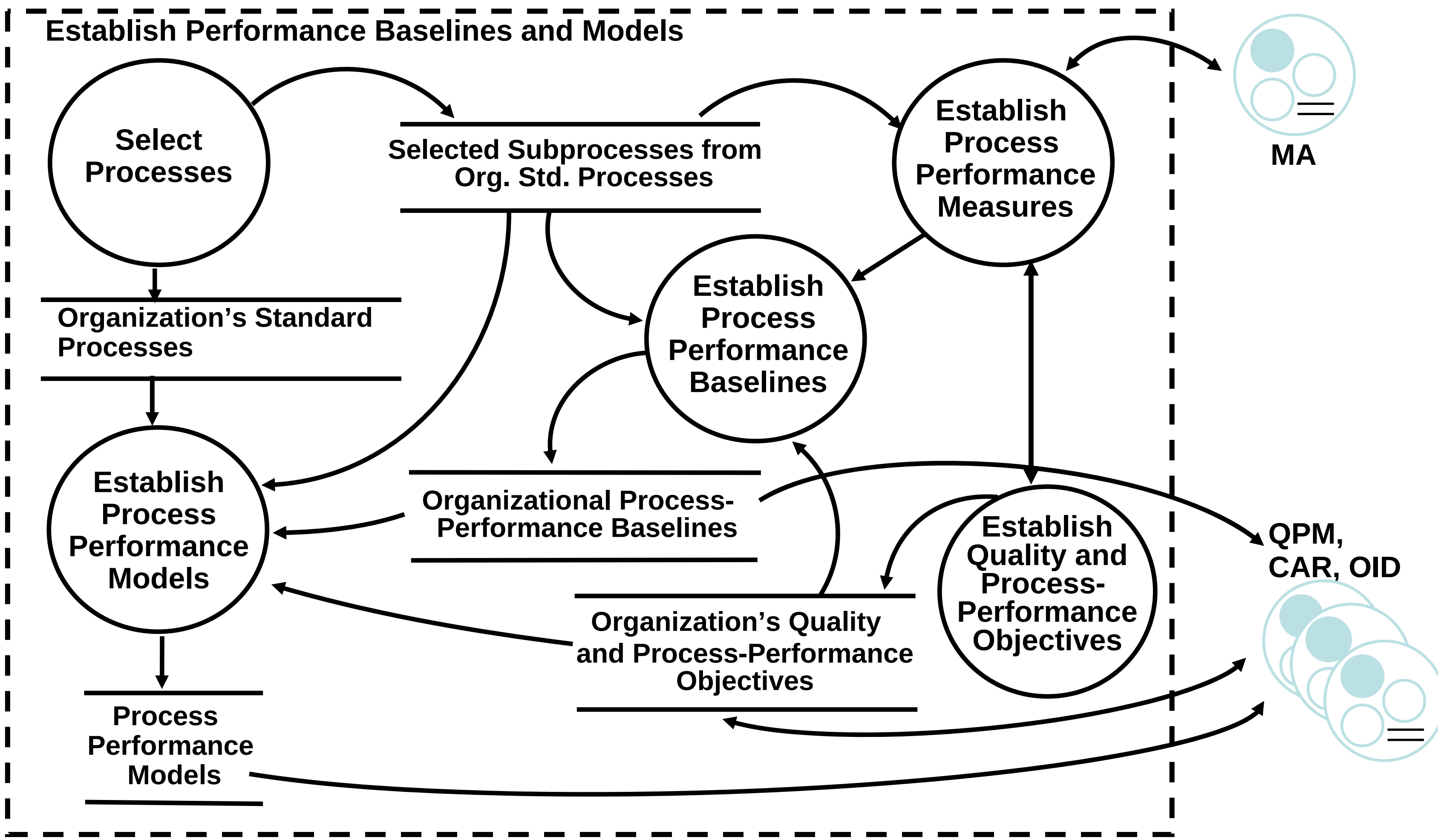
Statistics provides the methods and tools needed to measure and analyze process behavior, draw conclusions (i.e., statistical inferences), and **decide** next steps.

Eleven Frequently Misinterpreted ML 4-5 Practices

ML4-5 Practice	% of Respondents	Rank	Cum %
OPP 1.5 - Establish PPMs	49%	1	19%
QPM 1.3 - Select Subprocesses Statistically Managed	25%	2	28%
QPM 1.2 – Compose Project Defined Process	23%	3	37%
OPP 1.4 - Establish PPBs	21%	4	45%
OPP 1.1 - Select [Sub] Processes	19%	5	52%
OID 1.2 - Innovations	19%	5	59%
QPM 2.3 - Monitor [Subprocess] Performance	17%	7	66%
QPM 1.4 - Manage Project Performance	9%	8	70%
QPM 2.2 - Understand Variation	9%	8	73%
OID 1.1 - Improvement Proposals	9%	8	77%
CAR 1.1 - Select Data for Analysis	9%	8	80%

Source: Pat O'Toole, ATLAS 007. 53 provided input regarding the ML4-5 practices that most lead to interpretation issues.

OPP Context Diagram

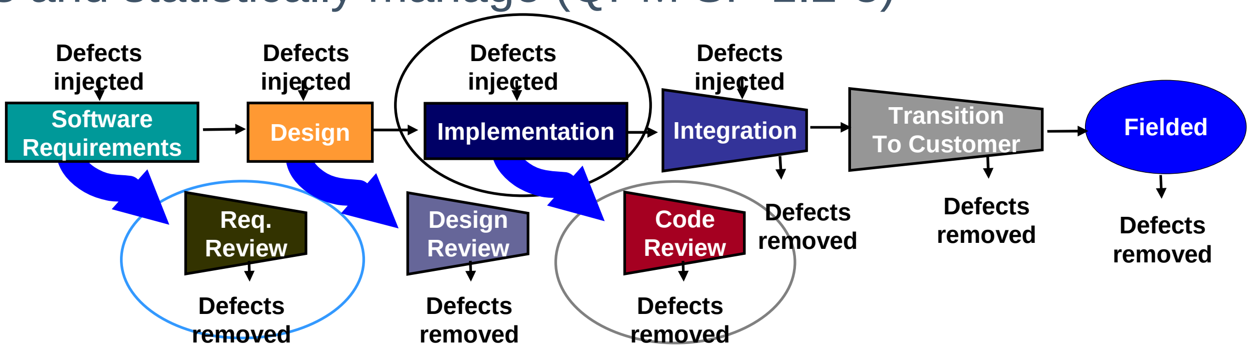


OPP SP 1.1 Select Processes -1

Select subprocesses that are critical to achieving the organization's objectives and to predicting whether or not they will be achieved.

This selection:

- is driven by objectives for quality and process performance (OPP SP 1.3)
- influences the selection of measures (OPP SP 1.2)
- is based on an analysis of PPBs and PPMs and influences their coverage (OPP SP 1.4-5)
- influences which subprocesses projects will use to compose their defined process and statistically manage (QPM SP 1.2-3)



OPP SP 1.1 Select Processes -2

Selecting appropriate processes must be based on clearly defined

- lifecycle models
- products and services
- organizational business objectives

Selected at the right granularity

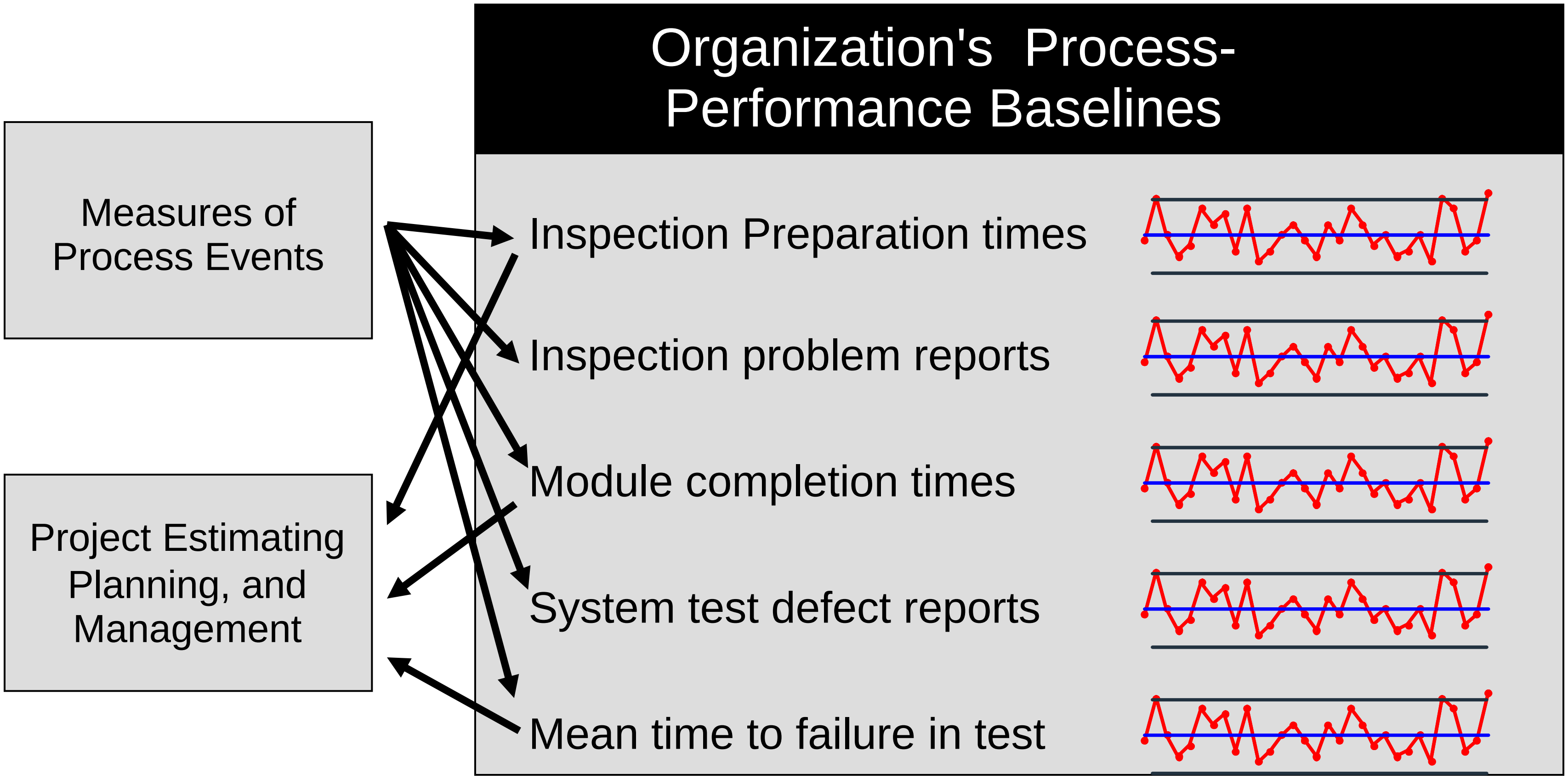
- large projects: lifecycle phases may be aggregates of subprocesses
- small projects: lifecycle phases may be the subprocesses
  - look at similar activities across multiple iterations, builds, and projects

Learn what works

- Use data to determine which subprocesses provide insight and control that help projects achieve their objectives
  - “control knobs”
  - leading indicators

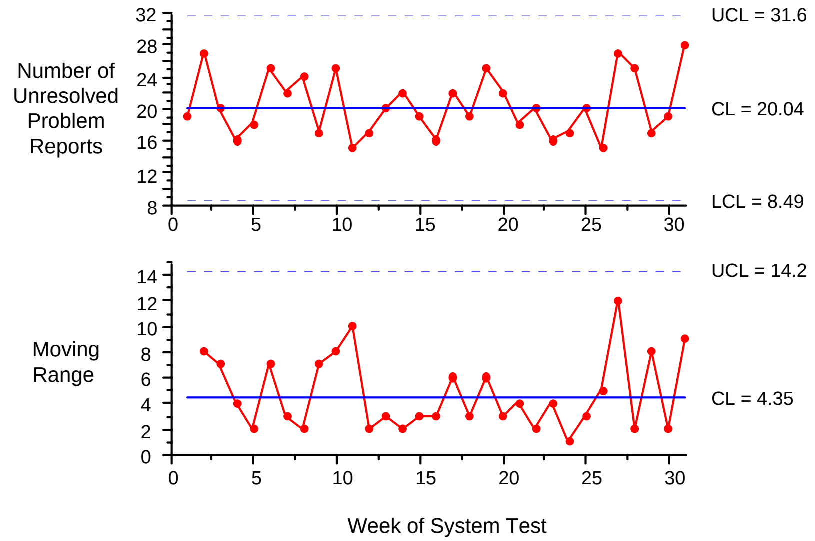
OPP SP 1.4 Establish PPBs -1

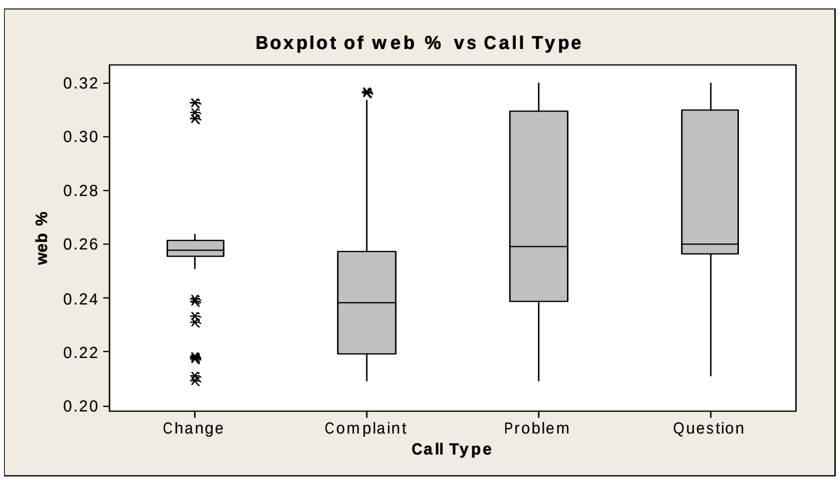
Process-performance baselines are built from project data.

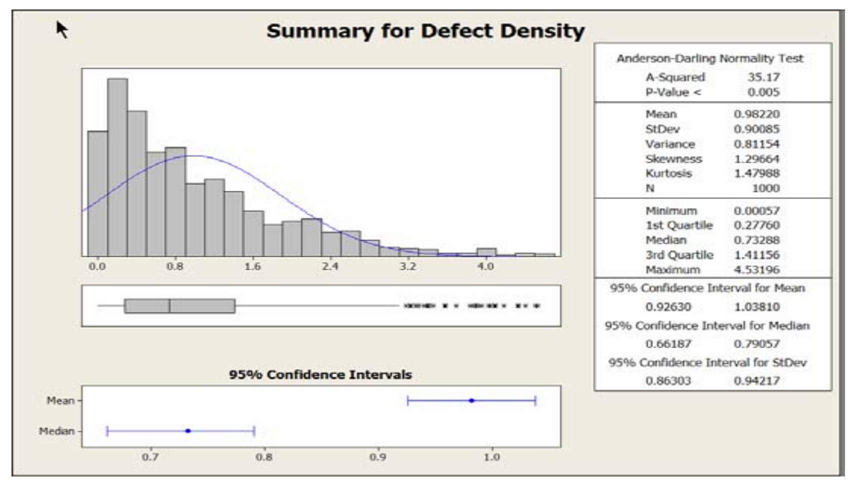


OPP SP 1.4 Establish PPBs -2

Process-performance baselines are derived by analyzing the collected measures to establish a distribution and range of results that characterize the expected performance for selected processes when used on any individual project in the organization.







How PPBs are Used

Establish and verify the reasonableness of organizational (OPP SP 1.3) and project objectives (QPM SP 1.1)

Compose the project's defined process (QPM SP 1.2)

Establish trial limits (QPM SP 2.2)

Identify potential sources of defects and problems (CAR SP 1.2)

Identify opportunities for improvement (OID SP 1.2)

Evaluate effects of a change on process performance in pilots and during or after deployment (e.g., a before-and-after comparison) (CAR SP 2.2; OID SP 1.3, 2.2-2.3)

PPB Lessons Learned

PPBs:

- are based on data available at a frequent enough rate and timely fashion
- are based on measures that have common operational definitions across projects to support organizational consolidation
- for time ordered as well as non-time ordered data
- address subprocess effort, cycle time, quality, and cost
- can include data from non-stabilized subprocesses (but flagged as such)

Some organizations try to start with only one set of PPBs (and PPMs) but later conclude that they need different sets for different product lines.

Projects may establish their own PPBs.

- provides for improved estimating and prediction within project

OPP SP 1.5 Establish PPMs

PPMs are used to estimate or predict the value of a process-performance measure from the values of other process and product measurements.

PPMs typically use process and product measurements collected throughout the lifecycle to estimate progress toward achieving objectives which cannot be measured until later in the lifecycle.

These models are defined to provide insight and to provide the ability to predict critical process and product characteristics that are relevant to business value.

The result of using a PPM to make a prediction often takes the form of a prediction interval (as opposed to a single point).

How PPMs are Used

Establishing/verifying reasonableness of organization (OPP SP 1.3) and project objectives (QPM SP 1.1-3)

Determining whether project is on track to meeting its objectives (QPM SP 1.4)

Analyzing/predicting impact, benefit, and ROI when evaluating/selecting:

- Defects and problems for analysis (CAR SP 1.1)
- Action proposals for implementation (CAR SP 2.1)
- Process improvement proposals for implementation (OID SP 1.1, 1.4)
- Candidate innovations (OID SP 1.2, 1.4)

Evaluating effects of a change on process performance to see if predicted performance is met (CAR SP 2.2, OID SP 2.2-2.3)

Essential Ingredients of PPMs -1

Relate the behavior or circumstance of a subprocess to an outcome.

Predict future outcomes based on possible or actual changes to factors (e.g. support “what-if” analysis).

Use factors from one or more subprocesses to conduct the prediction.

- The factors used are preferably controllable so that projects may take action to influence outcomes.

Are statistical or probabilistic in nature rather than deterministic (e.g. they account for variation in a similar way that QPM statistically accounts for variation; they model uncertainty in the factors and predict the uncertainty or range of values in the outcome).

Essential Ingredients of PPMs -2

High maturity organizations generally possess a collection of process-performance models that go beyond predicting cost and schedule variance, based on Earned Value measures, to include other performance outcomes.

Specifically, the models predict quality and performance outcomes from factors related to one or more subprocesses involved in the development, maintenance, service, or acquisition processes performed within the projects.

Process-performance models must provide useful insight for projects to use them as value-added tools.

Example Subprocesses to Be Modeled

Lifecycle phase subprocesses

- e.g. Req'ts, Architecture, Design, Code and Test (cycle time, quality performance or defect density, productivity, staff attributes, or risk indices)

Those contributing to resolution of inquiries or actions related to key communication interface subprocesses

- e.g. with suppliers, customers, partners

Inspection and peer review subprocesses

- e.g., preparation rates, review rates, defects found densities

Those contributing to downtime of essential parts of the project environment

- e.g., computing resources, test equipment, specialized tools and compilers

Types of Models

Basic statistical prediction models

- basic statistics to predict outcomes

Monte Carlo simulation and Optimization models

- automated “what-if” analysis of uncertain factors and decisions in a spreadsheet

Process simulation models

- actually model process activities w/computer

System dynamics models

- same as above but with real-time feedback loops

Probabilistic models

- prediction using laws of probability instead of statistics

Reliability growth models

- fitting test failure data to known distributions for enabling predictions of future failure experience

Basic Statistical Prediction Models

X \ Y	Continuous	Discrete
Discrete	ANOVA & MANOVA	Chi-Square & Logit
Continuous	Correlation & Regression	Logistic Regression

Example ANOVA:

- What are the escaped defect densities (e.g., defects per KSLOC) for each type of peer review (e.g. inspection, walkthrough), and are the densities statistically different by peer review type?

Monte Carlo Simulation

Allows modeling of variables that are uncertain (e.g. put in a range of values instead of single value)

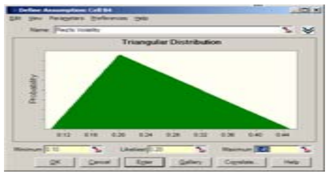
Enables more accurate sensitivity analysis

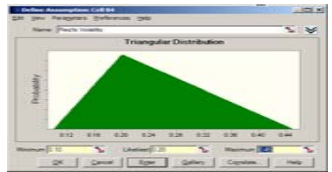
Analyzes simultaneous effects of many different uncertain variables (e.g. more realistic)

Eases audience buy-in and acceptance of modeling because their values for the uncertain variables are included in the analysis

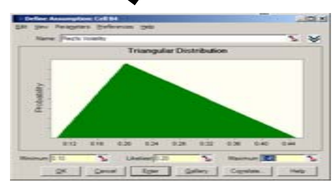
Establish confidence levels to outcomes (e.g. supports risk management)

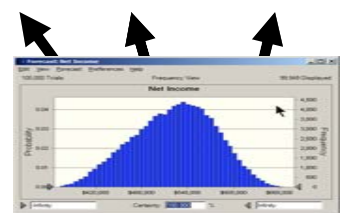
Example: Building a Business Case from the Defect Model



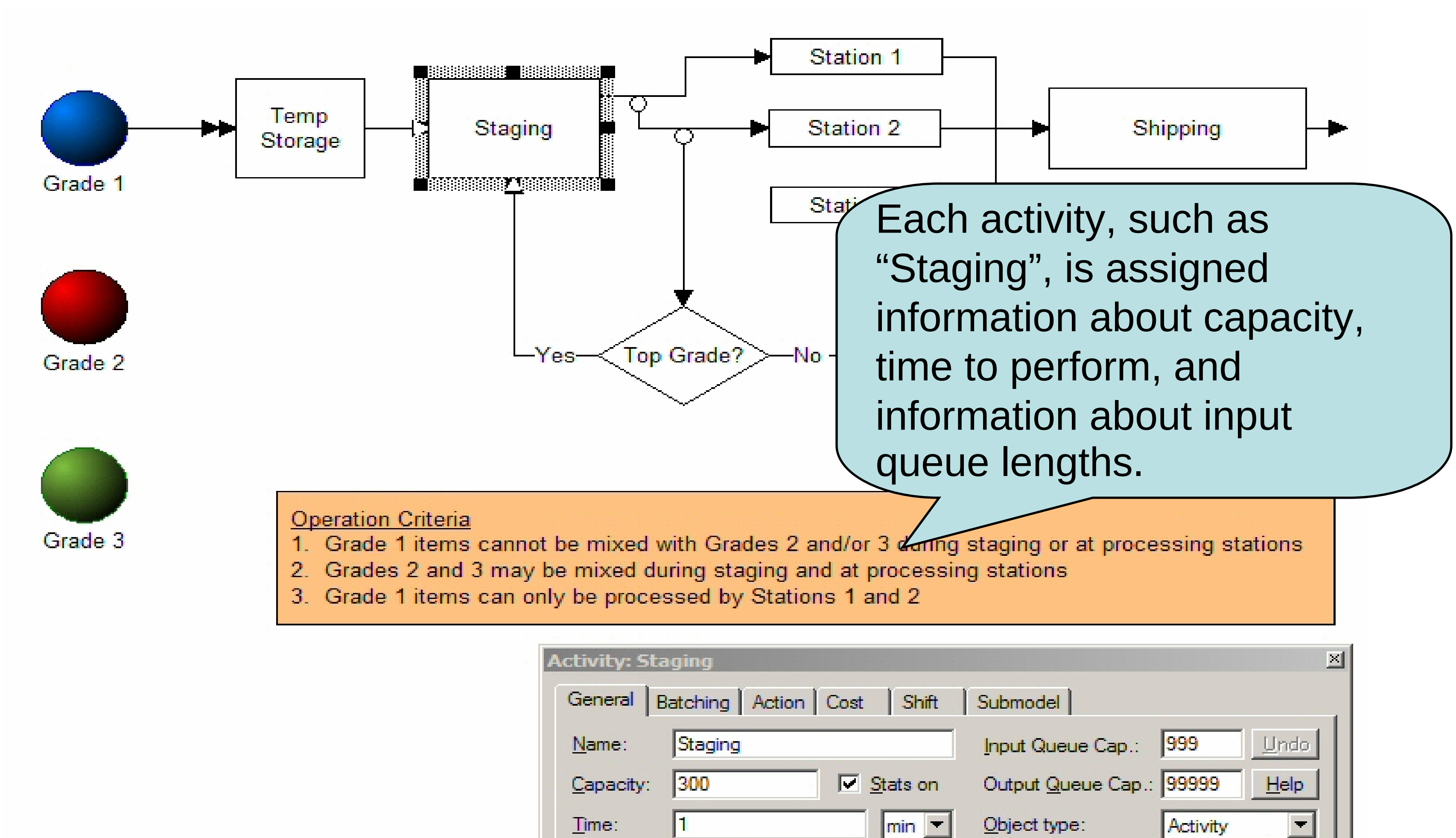


Phase Found	Phase Injected	Pre-Existing (SEG)	Pre-Existing (Contr)	Proposal	Planning	Design	Implement	Formal Test	Release	Total	Cost to Correct Prior to Delivery	Cost to Correct After Delivery (based on Industry Standards)	Cost Avoidance
Proposal	# of Defect	1	177	1764	0	[illegible]	0	0	0	1942			
	Rework (Hrs)	4	32.8	467.65	0	0	0	0	0	504.45	$45,400.50	$4,540,050.00	$4,494,649.50
Planning	# of Defect	0	1	14	1019	0	0	0	0	1034			
	Rework (Hrs)	0	1	3.4	172.07	0	0	0	0	176.47	$15,882.30	$1,588,230.00	$1,572,347.70
Design	# of Defect	0	26	8	14	2187	0	0	0	2235			
	Rework (Hrs)	0	17.35	320.91	7.75	851.42	0	0	0	1197.43	$107,768.70	$10,776,870.00	$10,669,101.30
Implement	# of Defect	1	28	15	27	61	4460	0	0	4592			
	Rework (Hrs)	0.1	30	5.85	0.71	244.5	2521.99	0	0	2803.15	$252,283.50	$2,522,835.00	$2,270,551.50
Formal Test	# of Defect	0	11	0	2	17	285	608	0	923			
	Rework (Hrs)	0	42	0	0.12	229.42	139.1	559.65	0	970.29	$87,326.10	$873,261.00	$785,934.90
Release	# of Defect	0	0	59	0	4	4	0	961	1028			
	Rework (Hrs)	0	0	[illegible]	0	43	8.3	0	152.24	213.15	$19,183.50	$191,835.00	$172,651.50
Total	# of Defect	2	243	[illegible]	1062	[illegible]	[illegible]	608	961	11754			
	Rework (Hrs)	4.1	123.15	[illegible]	180.65	[illegible]	2669.39	559.65	152.24	5864.94	$527,844.60	$20,493,081.00	$19,965,236.40



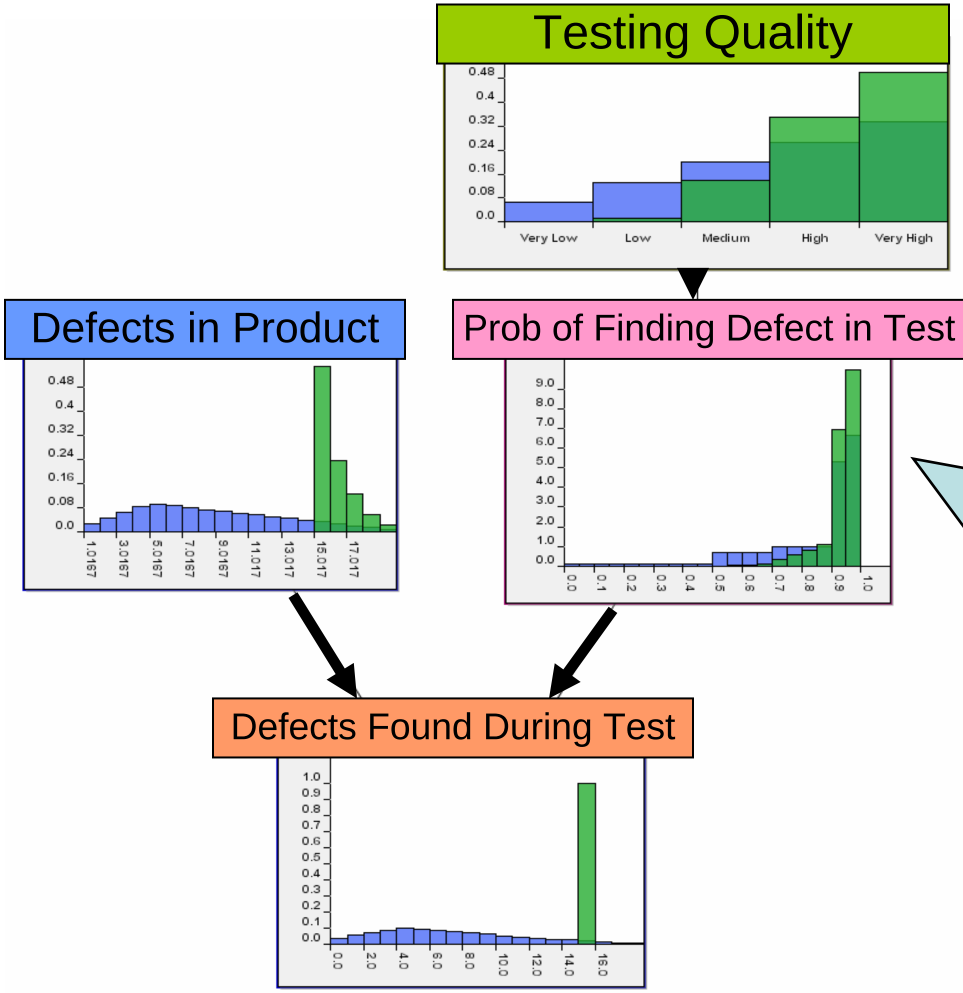


Process Modeling Simulation



Adapted from ProcessModel, Inc.

Bayesian Belief Network Quality Model



We can predict the probability of finding a defect during a test, by learning what the quality of testing is.

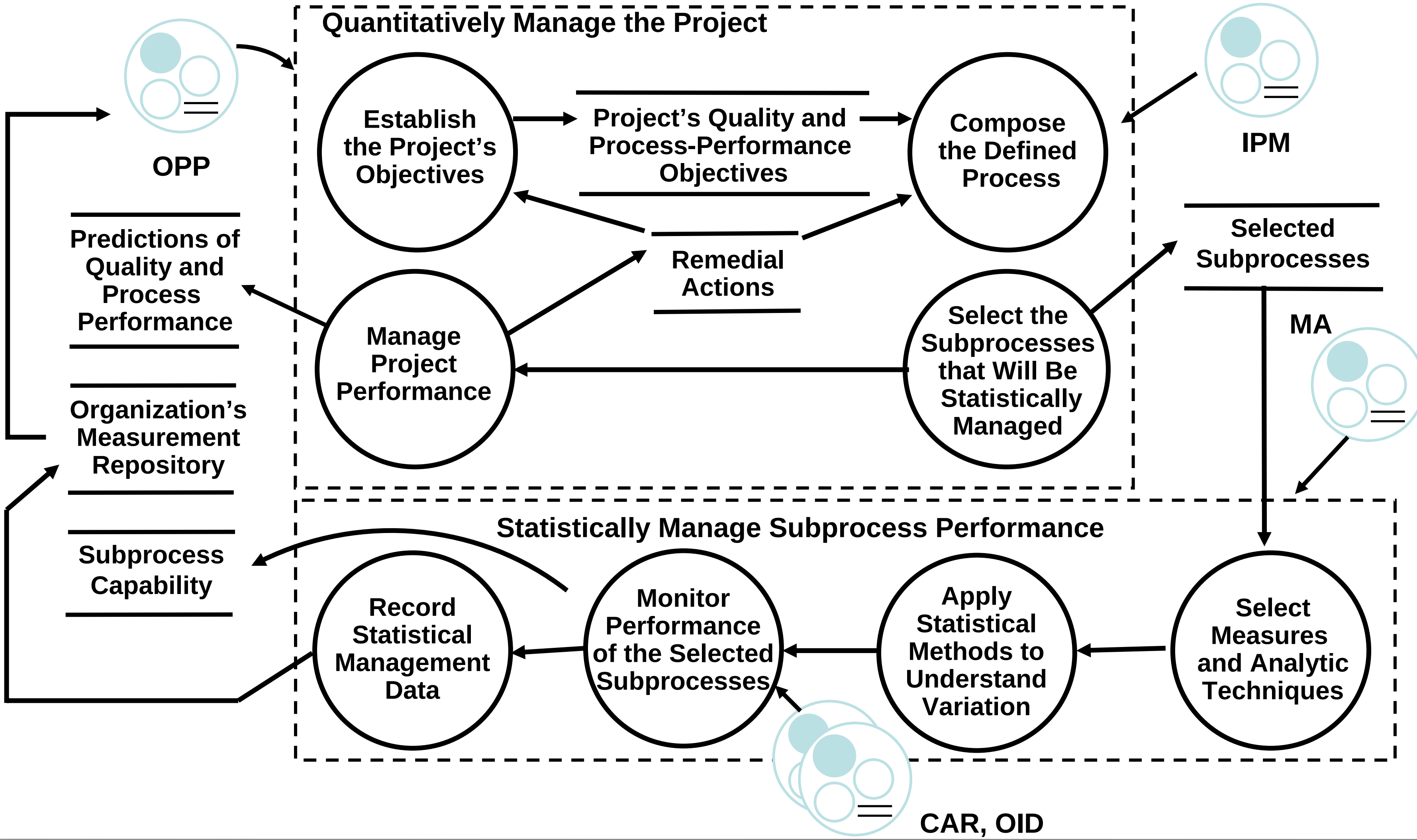
Also, we can predict defects found by learning more about the expected incoming defect level and our ability to find defects with testing!

From AgenaRisk, Ltd

Six Sigma/Modern Statistics Essential to OPP

SP1.1 Processes	Big Y Business Goal-to-Vital x Process; Processes driving central tendency and variation
SP1.2 Measures	Critical Parameter Management; CTQ factors; Root Cause Analysis of subprocess factors
SP1.3 Objectives	KJ Analysis®; Analytic Hierarchy Process; Categorical Survey Data Analysis; Six Sigma Scorecards
SP1.4 Baselines	Control Charts; Graphical Summaries in Minitab; Central Tendency and Variation; Confidence and Prediction Intervals
SP1.5 Models	ANOVA; Regression; Chi-Square; Logistic Regression; Monte Carlo Simulation; Discrete Event Process Simulation; Design of Experiments; Response Surface Methodology; Multiple Y Optimization; Probabilistic Models

QPM Context Diagram



Relevant Terminology

Statistical management (QPM SG 2)

Management involving statistical thinking and the correct use of a variety of statistical techniques, such as run charts, control charts, and prediction intervals.

Quantitative management (QPM SG 1)

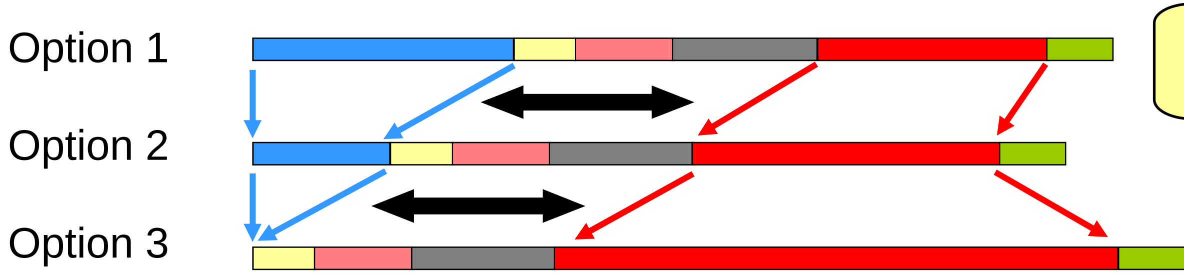
The process of using data from statistical and other techniques to manage the project

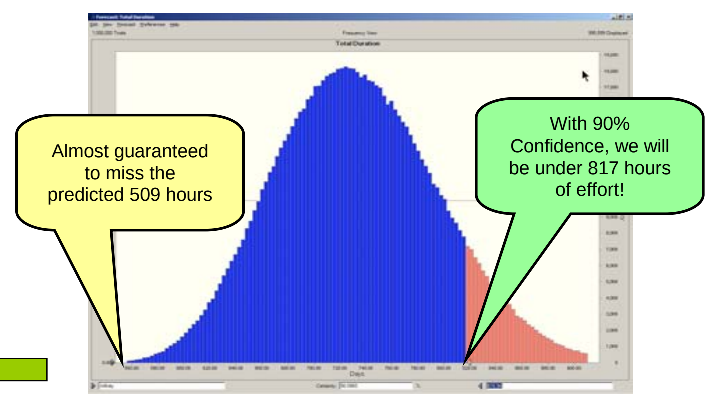
- predict whether it will be able to achieve its quality and process-performance objectives
- identify what corrective action (if any) should be taken

QPM SP 1.2 Compose the Defined Process

With what process composition can the project best meet its objectives?

- selects the subprocesses that helps it best achieves its goals
- may try different compositions of subprocesses
  - build a PPM of each candidate composed process to predict if the goals will be achieved
  - if no candidate process is predicted to achieve the project’s objectives
    - CAR can help find improvements to the process to achieve the objectives.
    - OID can help identify innovations that will enable meeting the objectives.
    - Modify PDP and Project PPM.





One Approach to PDP Composition

Problem
Produce a product in a given period of time with an acceptable minimum level of quality.

Step 1
Examine the baselined subprocesses:

- Are there appropriate lifecycle processes?
- Are there options with differing performance characteristics?

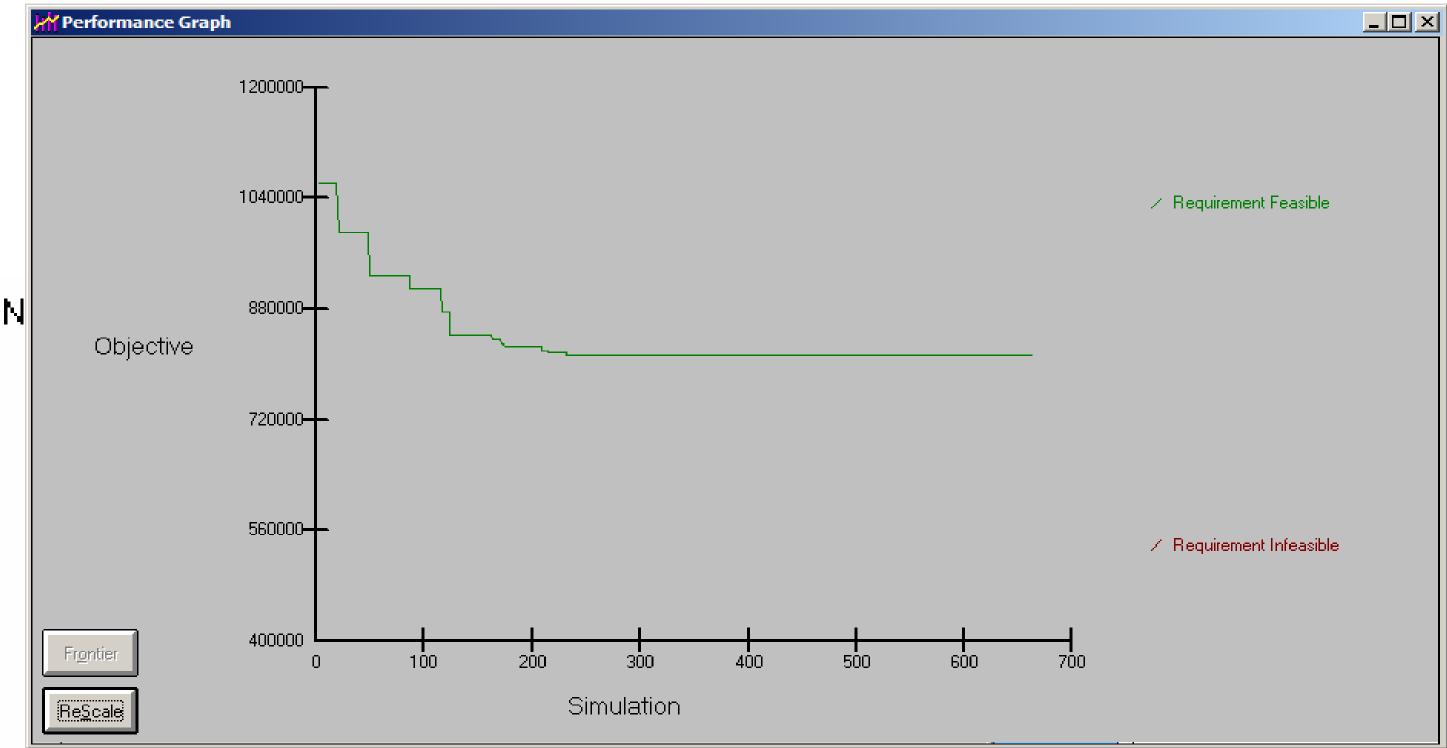
Step 2
Load a Monte Carlo simulation with candidate subprocesses, their data (PPBs), and constraints (e.g., subprocess A won't work with subprocess B).

Step 3

Establish optimization priorities. Run the Monte Carlo simulation.

Step 4
Evaluate the simulation outputs to determine if the candidate subprocesses will solve the problem.

Monte Carlo Optimization for Quality



****BEST SOLUTION

Values of Variables:
RD Decision: 1
RR Decision: 4
Design Decision: 2
DR Decision: 4
Code Decision: 4
CR Decision: 2
UT Decision: 1
IT Decision: 3
ST Decision: 3
AT Decision: 1
Objective: Overall Goal: Mean: 8122
Requirement Feasible
Requirement: TEST01: 0
Requirement: TEST02: 0
Requirement: TEST03: 0
Additional details may be found below...

This solution of process composition is optimized with first priority of quality and secondary priority on cycle time. Run additional simulations reflecting alternative optimization priorities.

Summary of Monte Carlo Results

Subprocesses	Optimize for	
	Cycle Time	Quality
Requirements Development	Traditional	Traditional
Requirements Review	Email Routing	Sampling Inspections
Design	SA/SD	OOD
Design Review	Email Routing	Sampling Inspections
Code	Code Generation w/Reuse	Code Generation w/Reuse
Code Review	Email Routing	Walkthrough
Unit Test	Ad Hoc	Ad Hoc
Integration Test	Hybrid	Hybrid
System Test	Production Hardware	Production Hardware
Acceptance Test	Low Intensity	Low Intensity
Results (95% Confidence results won't exceed)		
Cycle Time	171	185
Quality Rework Costs	$487,000	$354,000
Overall Costs	$7,935,000	$841,000

QPM SP 1.3 Select the Subprocesses that Will Be Statistically Managed -1

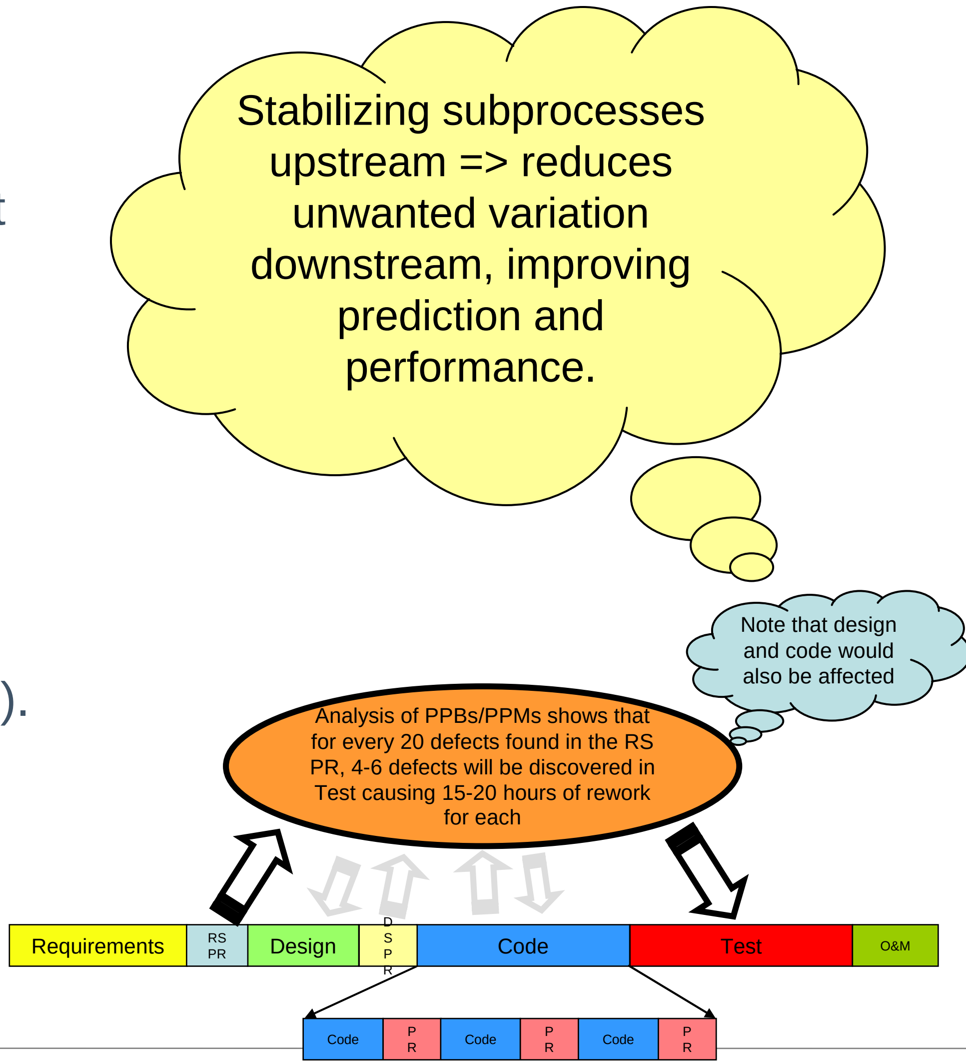
The project selects the subprocesses it will statistically manage to help it meet its objectives (QPM SP 1.1).

- Decision is based, in part, on the organization's selected subprocesses for organizational process-performance analyses (OPP SP 1.1).
  - And on the subprocesses composing the PDP (QPM SP 1.2).
- The selected subprocesses then become the "subject" of the SPs of SG 2 Statistically manage subprocess performance

QPM SP 1.3 Select the Subprocesses that Will Be Statistically Managed -2

Determine important subprocess attributes

- Which attributes provide insight into subprocess performance?
- Which attributes most affect downstream performance?
- Perform sensitivity analyses.
- Improve PPM coverage of upstream subprocesses (at project and organizational level).

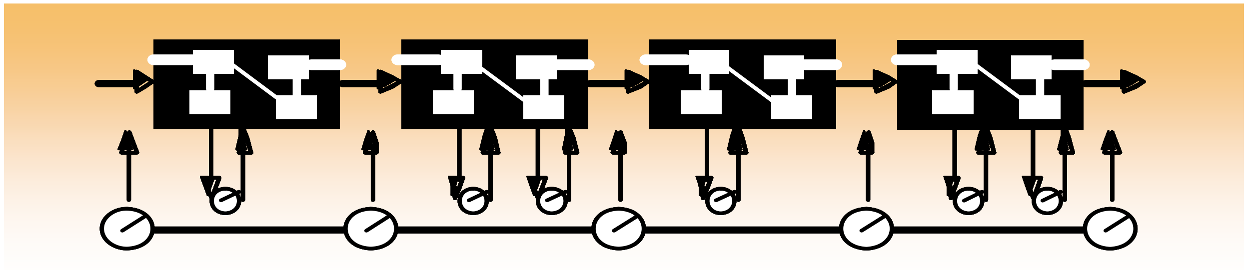


SP 1.4 Manage Project Performance

Periodically evaluate progress toward achieving the project's quality and process-performance objectives by doing the following:

- review the capability of each selected subprocess
- review the actual results achieved against the interim performance targets for that phase
- review results of suppliers against their performance targets
- calibrate PPMs to estimate progress

If not on track, evaluate options for corrective action by using adjusted PPBs and PPMs to predict the effects an option will have ("what if?"); thereby determining which is the best option for getting back on track.

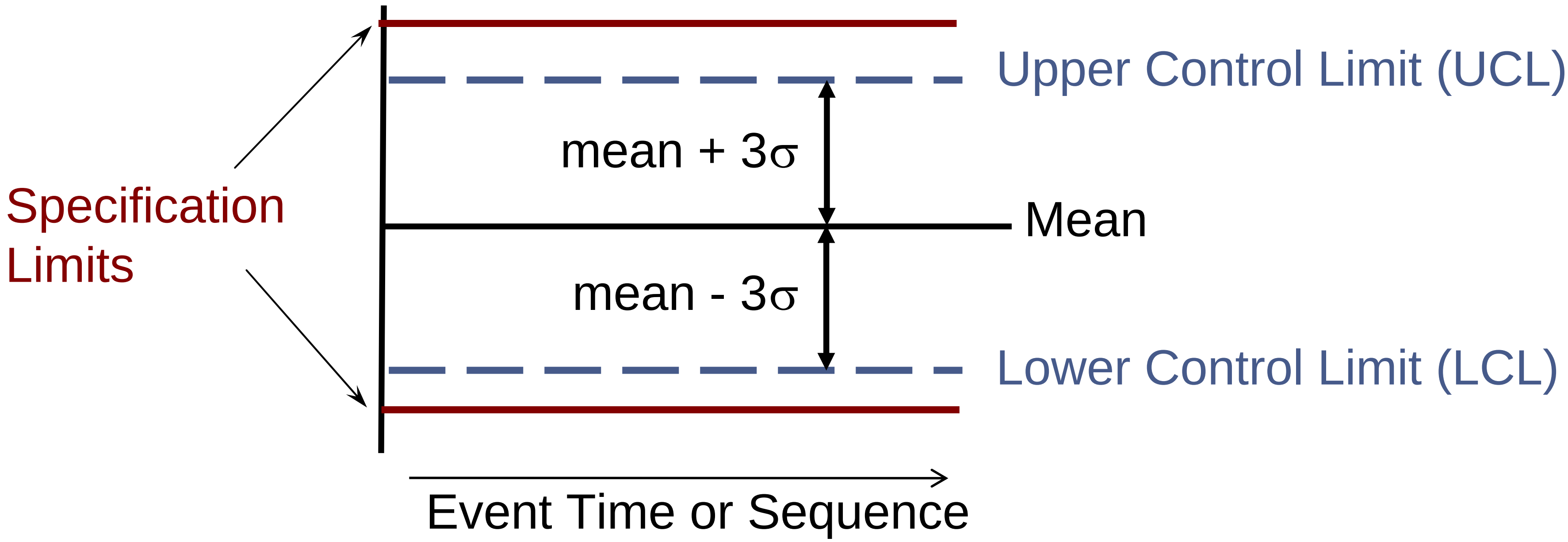


QPM SP 2.2 Apply Statistical Methods to Understand Variation

Establish and maintain an understanding of the variation of the selected subprocesses using the selected measures and analytic techniques.

1. Establish trial natural bounds for subprocesses having suitable historical performance data.
2. Collect data, as defined by the selected measures, on the subprocesses as they execute.
3. Calculate the natural bounds of process performance for each measured attribute.
4. Identify special causes of variation.
5. Analyze the special cause of process variation to determine the reasons the anomaly occurred.
6. Determine what corrective action should be taken when special causes of variation are identified.
7. Recalculate the natural bounds for each measured attribute of the selected subprocesses as necessary.

Control Charts



Control Limits → Set by analyzing historical process data (Voice of the process)

Specification Limits → Set by customer, engineer, etc. (Voice of the customer)

Understanding Variation and Level 4 -1

A common misconception is that because you are using control charts, you are ML4. Using control charts is only one statistical method that aids in understanding process variation.

Instead, ML4 (more precisely, QPM) requires that you understand process variation for selected subprocesses and quantitatively manage the project based on that understanding.

The understanding of process variation becomes the basis for the following:

- determining when to take corrective action
- predicting future performance
- determining whether the subprocess is capable of achieving its quality and process performance objectives

Understanding Variation and Level 4 -2

When control limits are too wide, sources of variation are easily masked (i.e., the process is not in control though it may appear to be) and future performance cannot be predicted.

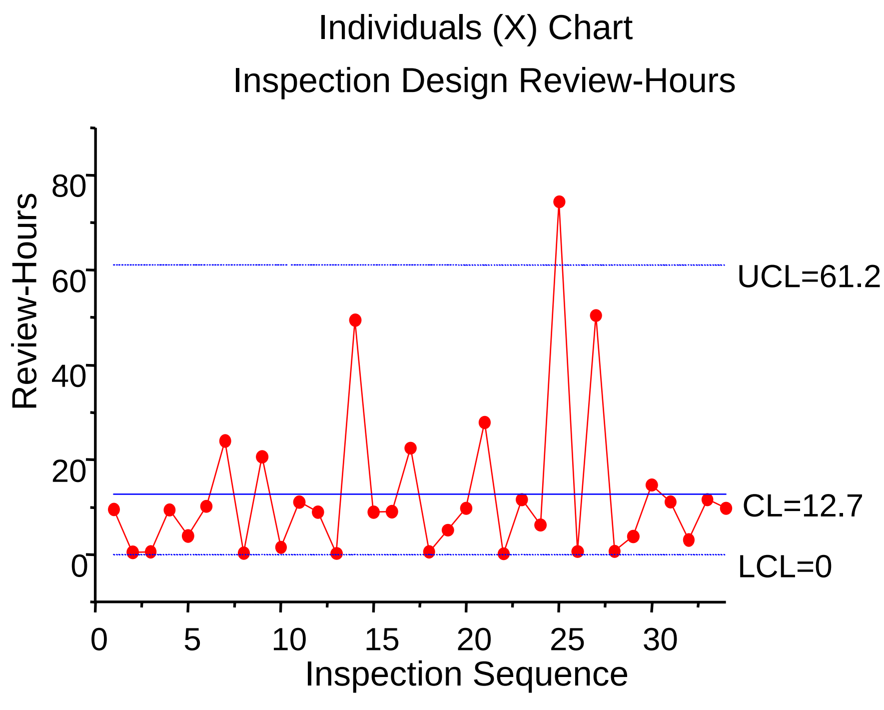
To improve predictability, investigate sources of variation by examining the following:

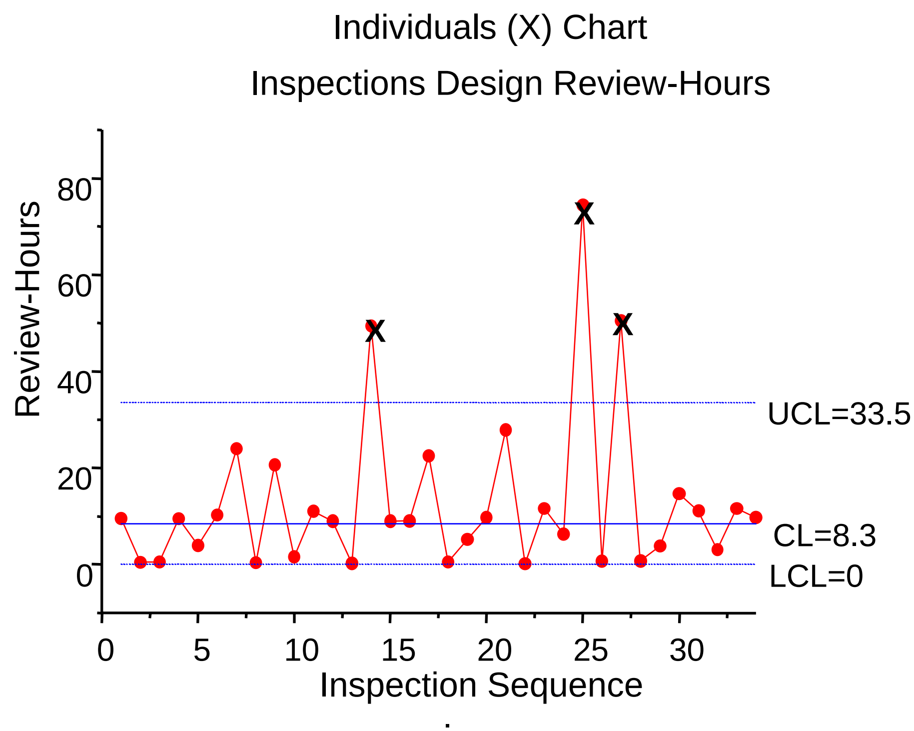
- upstream subprocesses
- various subgroups of the data (e.g., data grouped by source or work product size)
- the measures being used

This investigation may lead to changes in which subprocesses and attributes are targeted for control.

Wherever possible, teams should use their own data for the same subprocess in order to better understand and stabilize a subprocess's performance.

Revising Control Limits UnMasks Other Sources of Variation





Notes on Using Control Charts

Some organizations want staff to check for normality before using XmR or XbarR

- Wheeler: don't need to worry about it
- Stoddard: easy to do, why not?

If data isn't normal should we transform it before placing on a control chart?

- Stoddard: usually don't gain much from doing this, and we easily lose intuition of what the control limits mean

Common pitfalls

- arbitrarily setting control limits
- freezing control limits
- removing points outside limits to show stability (but without investigating these)

QPM SP 2.3 - Monitor Performance of the Selected Subprocesses

Monitor the performance of the selected subprocesses to determine their capability to satisfy their quality and process-performance objectives, and identify corrective action as necessary.

1. Compare the quality and process-performance objectives to the natural bounds of the measured attribute.
2. Monitor changes in quality and process-performance objectives and selected subprocess' process capability.
3. Identify and document subprocess capability deficiencies.
4. Determine and document actions needed to address subprocess capability deficiencies.

Stability, Capability, and Voices

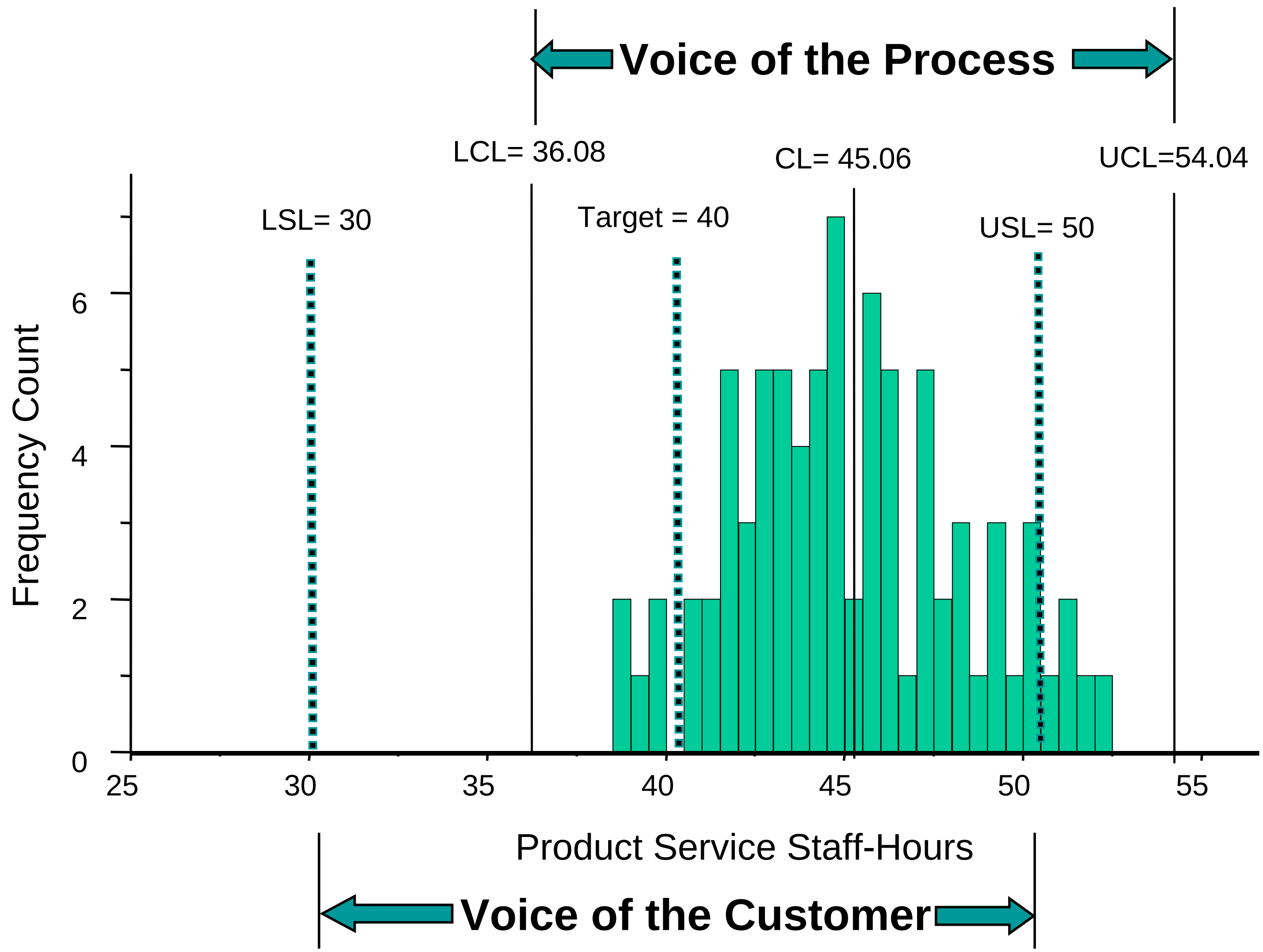
SP 2.2 is about determining the voice of the subprocess and achieving a stable subprocess.

- A stable subprocess is the state in which all special causes of process variation have been removed and prevented from recurring so that only the common causes of process variation remain.

SP 2.3 is about comparing the voice of the subprocess to the voice of the customer to determine if the subprocess is capable.

- A capable subprocess is a process that can satisfy its specified product quality, service quality, and process-performance objectives.
- Thus, having a stable subprocess is prerequisite to SP 2.3.

A Capable Process?



Stability, Capability, Limits, and Models -1

The Basics

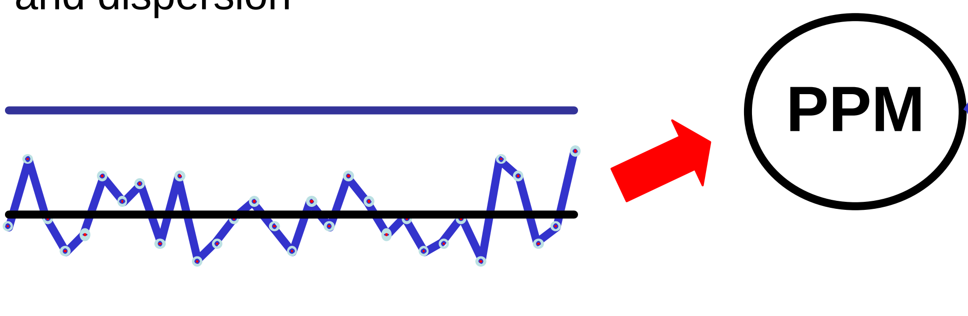
Start with a

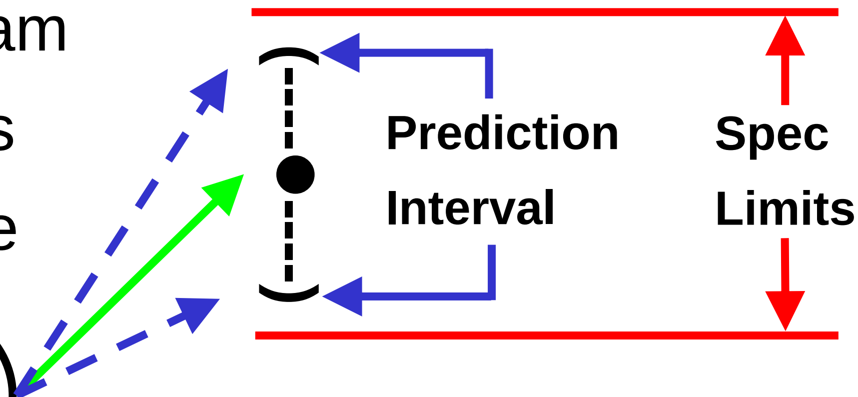
stabilized process

or at least one for which we know the central tendency and dispersion

Use a PPM to predict a downstream process attribute

Which determines a prediction interval for that attribute





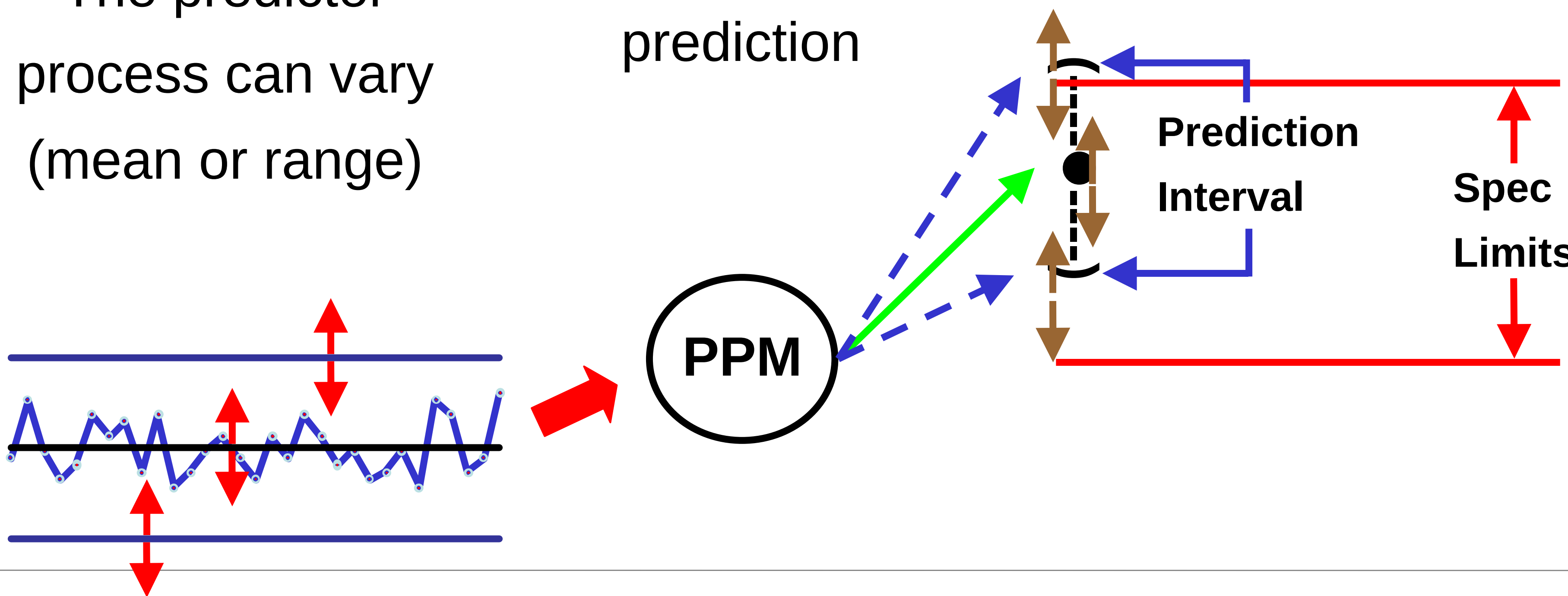
Stability, Capability, Limits, and Models -2

What can happen

The predictor process can vary (mean or range)

PPM produces a new prediction

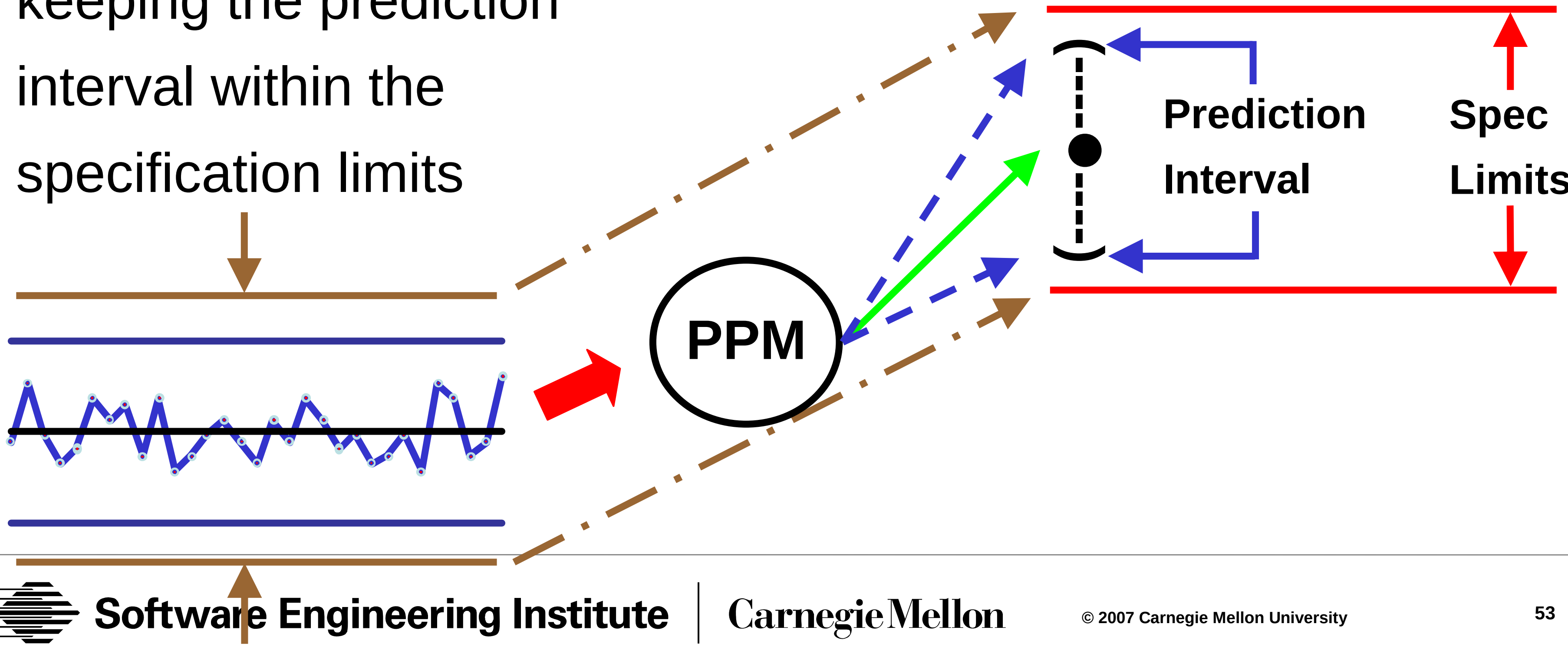
Which suggests we’re no longer on track to meeting our objectives



Stability, Capability, Limits, and Models -3

The Tolerance Interval

Tolerance interval shows how much the predictor process can vary while keeping the prediction interval within the specification limits



Six Sigma/Modern Statistics Essential to QPM

SG1 Quantitatively Manage the Project

KJ Analysis; Analytic Hierarchy Process; Categorical Survey Data Analysis; Six Sigma Scorecards; Big Y Business Goal-to-Vital x Process; Process Mapping Methods and Value-Stream Analysis;
Processes driving central tendency and variation; Critical Parameter Management; CTQ factors; Root Cause Analysis of Sub-process factors; Cockpit

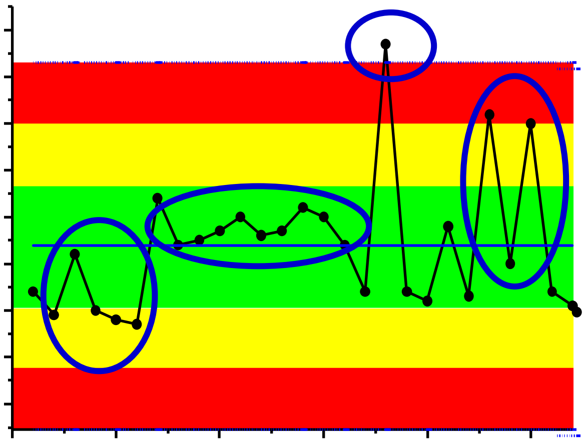
SG2 Statistically Manage Subprocess Performance

Control Charts; Graphical Summaries in Minitab; Central Tendency and Variation; Confidence and Prediction Intervals; ANOVA; Regression; Chi-Square; Logistic Regression; Monte Carlo Simulation; Discrete Event Process Simulation; Design of Experiments; Response Surface Methodology; Multiple Y Optimization; Probabilistic Models

CAR Application at Higher Levels

During project execution, issues arise that CAR can help solve:

- No process can be composed that will meet objectives (QPM SP 1.2)
- Project will not achieve its objectives (QPM SP 1.4)
- Subprocess control limits (or prediction interval) spread too far apart to be of much value in control and prediction (QPM SP 2.2)
- Special causes of variation (QPM SP 2.2)
- Subprocess not capable (QPM SP 2.3)



CAR SP 1.1 Select Defect Data for Analysis

When selecting (sets of) defects or problems for further analysis, consider the following:

- impact
- frequency of occurrence
- similarity between defects
- cost of analysis
- time and resources needed
- safety considerations
- ROI

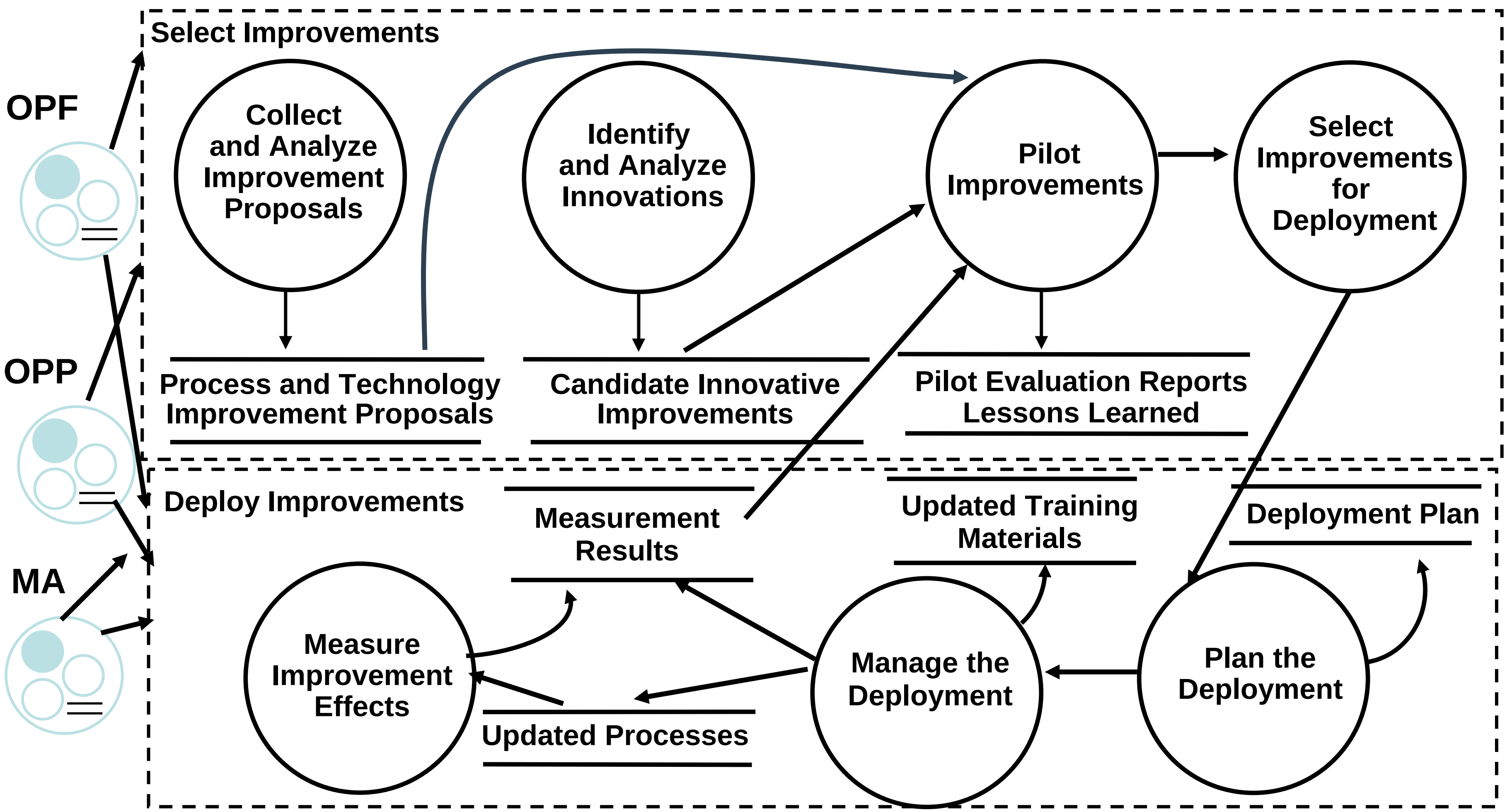
PPBs and PPMs can be useful for: (1) identifying defects or problems to work on, (2) analyze root causes, (3) predicting the impact and ROI of potential solutions, and (4) confirming the impact after deployment.

Your cost/benefit analyses should also consider impacts to the capability of the process.

Six Sigma/Modern Statistics Essential to CAR

SP1.1 Select Defect Data for Analysis	Measure Phase (within DMAIC or DMAD(O)V) tools and methods; Models provide insight to the areas of defect data to concentrate on
SP1.2 Analyze Causes	Root Cause Methods, e.g. Ishikawa Diagrams, statistical hypothesis tests to determine if segments are different
SP2.1 Implement the Action Proposals	Piloting; Comparative Studies; Technological and Cultural Change Management techniques
SP2.2 Evaluate the Effect of Changes	Before and After studies and Hypothesis tests; Survey categorical data analysis; compare to results of prediction models
SP2.3 Record Data	Study results; Lessons Learned shared across the organization; Institutional learning

OID Context Diagram



How OID SP 1.1 and 1.2 Interrelate

Process improvement proposals submitted from engineering, management, suppliers, customers, etc.

Collect and analyze process improvement proposals to determine costs, benefits, risks, and barriers (OID SP 1.1).

- Use PPMs to predict the performance of the revised process and to facilitate cost/benefit analysis.

Identify areas where improvements would be beneficial and the technologies and innovations that target those areas (OID SP 1.2):

- Use PPBs and PPMs to identify potential areas for improvement.
- Identify innovations to address the areas needing improvement.
- Use PPMs to predict impacts, costs, and benefits of particular innovations.
- Create process improvement proposals for promising innovations.

OID SP 1.1 Collect and Analyze Improvement Proposals -1

Sources for improvement proposals include:

- Causal analysis activities
- Process- and technology-improvement proposals
- Investigation of innovative improvements
- Analysis of PPBs and PPMs
- findings and recommendations from process appraisals
- analysis of customer and end-user problem and satisfaction data
- analysis of data about project performance compared to objectives
- examples of improvements that were successfully adopted outside the organization
- analysis of technical performance measures
- results of process and product benchmarking efforts
- feedback on previously submitted proposals
- spontaneous ideas from managers and staff

Mature organizations, because of their refined segmentation of process and technology, can work in a more focused fashion to gather their benchmarking data.

OID SP 1.1 Collect and Analyze Improvement Proposals -2

Improvement proposal costs and benefits are evaluated using criteria:

- contribution toward meeting the organization's quality and process-performance objectives
- effect on mitigating identified project and organizational risks
- effect on related processes and associated assets
- cost of defining and collecting data that supports the measurement and analysis of the process- and technology-improvement proposal
- expected life span of the proposal

PPMs can be used to predict what performance would result from process changes, thus, facilitating cost benefit analyses.

- We will show an example of this for SP 1.2.

OID SP 1.2 Identify and Analyze Innovations

Identify and analyze innovative improvements that could increase the organization's quality and process performance.

1. Analyze the organization's set of standard processes to determine areas where innovative improvements would be most helpful.
2. Investigate innovative improvements that may improve the organization's set of standard processes.
3. Analyze potential innovative improvements to understand their effects on process elements and predict their influence on the process.
4. Analyze the costs and benefits of potential innovative improvements.
5. Create process- and technology-improvement proposals for those innovative improvements that would result in improving the organization's processes or technologies.
6. Select the innovative improvements to be piloted before broadscale deployment.
7. Document the results of the evaluations of innovative improvements.

The Role of Analyses in OID SP 1.2

The subpractices of SP 1.2 mention performing various analyses.

These analyses are performed to determine which subprocesses are critical to achieving the organization's quality and process-performance objectives – either as direct contributors and/or as leading indicators.

- Use PPBs and PPMs to determine which factors to target for innovation (i.e., to determine which subprocesses to improve).
- When a factor is selected as a target for innovation, use PPBs and PPMs to evaluate the impacts, costs, and benefits of candidate innovations ("what ifs") within that area.

The PPBs and PPMs mentioned above may already exist, or they may need to be developed to support performing these analyses.

Investigate Innovative Improvements

Investigating innovative improvements involves the following:

- systematically maintaining awareness of leading relevant technical work and technology trends
- periodically searching for commercially available innovative improvements
- collecting proposals for innovative improvements from projects and the organization
- systematically reviewing processes and technologies used externally and comparing them to those used within the organization
- identifying areas where innovative improvements have been used successfully, and reviewing relevant data and documentation
  - Difficult-to-meet objectives may have led some projects to compose a defined process (QPM SP 1.2) having promising performance characteristics
- identifying improvements that integrate new technology into products and project work environments

Using PPBs and PPMs to Select an Area to Improve -1

First, some terminology:

Defect density at release (DD) is the number of defects per unit of product size (e.g., KLOC) in the product at release.

Requirements volatility (RV) is the rate at which requirements change once design begins, e.g., % requirements statements (or use cases) changed, annualized per year.

Design complexity (DC) is the number of unique subtrees in the calling-tree hierarchy*.

Effectiveness of quality checks (QC) is a measure (e.g., a count) of the items that have been addressed on a check sheet for requirements and design verification.

Staff turnover (ST) is a measure of project team churn, e.g., # of staff replaced on the project team, annualized per year.

* See “Design Complexity Measurement and Testing,” by Thomas J. McCabe and Charles W. Butler, CACM, Dec. 1989, for more information.

Using PPBs and PPMs to Select an Area to Improve -2

Assume an organizational objective for product quality:

- Defect density at release (DD) < 0.4 defects/size unit

is not often met.

Use a formal evaluation process (DAR) to determine which factors (i.e., “areas”) to focus on.

Step 1. Establish criteria for evaluating factors that impact DD.

- Example criteria include:
  - contribution to (i.e., influence on) DD
  - potential for innovations in that factor
  - potential costs and risks (or opportunities) associated with changing that factor

Using PPBs and PPMs to Select an Area to Improve -3

Step 2. Identify factors that impact DD.

Perform a regression analysis creating a PPM that shows the relationship between DD and several contributing factors:

- requirements volatility (RV)
- design complexity (DC)
- effectiveness of quality checks (QC)

Of course, such a PPM might already exist.

Re-run the regression analysis, as appropriate, to evaluate additional promising factors, e.g., staff turnover (ST).

Using PPBs and PPMs to Select an Area to Improve -4

Results for: **Defect Density Process Performance Model**

Regression Analysis: **Defect Density versus RV, DC, QC**

The regression equation is

Defect Density = 389 + 2.12 **RV** + 5.32 **DC** - 24.1 **QC**

Predictor	Coef	SE Coef	T	P
Constant	389.17	66.09	5.89	0.000
RV	2.125	1.214	1.75	0.092
DC	5.3185	0.9629	5.52	0.000
QC	-24.132	1.869	-12.92	0.000

4% R-Sq(adj) = 85.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	12833.9	4278.0	57.87	0.000
Residual Error	25	1848.1	73.9		
Total	28	14681.9			

Evaluate whether requirements volatility (RV), design complexity (DC), and effectiveness of quality checks (QC) have an impact on DD.

(An analysis with staff turnover is not shown here.)

PPMs help select areas to target for innovation.

Note the p-values for RV vs. DC, QC.

Using PPBs and PPMs to Select an Area to Improve -5

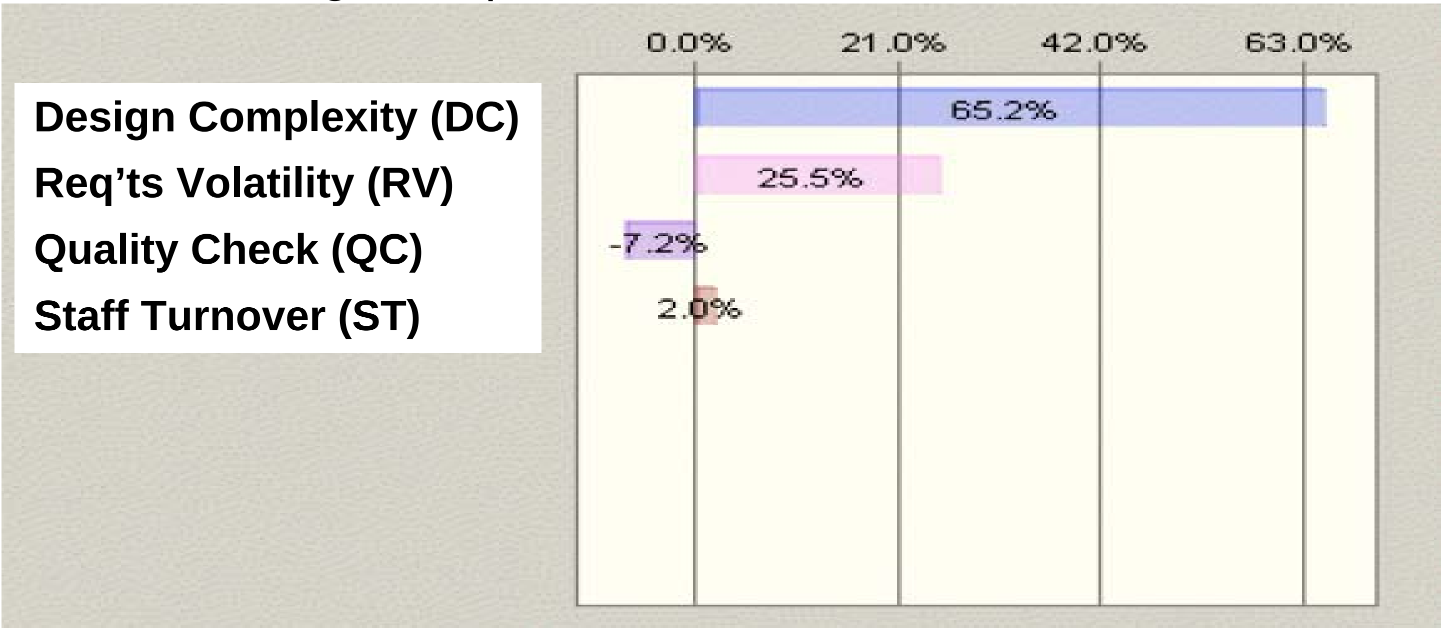
Step 3. Evaluate the factors using the established criteria.

How do we evaluate “contribution to DD?” Several analysis tools are available to help. For example, Crystal Ball (www.crystalball.com) provides:

- Tornado Chart – screens out factors with little contribution potential to allow for a more vigorous simulation-based sensitivity analysis.
- Sensitivity analysis – performs a Monte Carlo simulation to derive estimates of the correlations between factors and the outcome (more broadly, “assumptions” and a “forecast”).
  - Results in a bar chart that ranks factors according to their influence on the variability of an outcome (DD in this case)
  - A bar’s direction indicates whether the correlation is positive or negative. (See next slide.)

Using PPBs and PPMs to Select an Area to Improve -6

Here is the result of a Crystal Ball-based sensitivity analysis. Note which factors have the largest impact on DD.



From the above steps (with possible iteration), the conclusion is design complexity (DC) is the most promising factor to target for improvement.

Detailed design is thus targeted for innovations that will help reduce DC.

Using PPBs and PPMs to Evaluate Candidate Innovations -1

A formal evaluation (DAR) is typically performed on candidate innovations.

As part of that evaluation, PPMs play an important role in predicting impacts, costs, and benefits from deploying the candidate innovation.

This helps determine whether piloting the innovation (and its possible subsequent deployment) is worth pursuing.

The role that a PPM might play is illustrated with an example.

Step 1. Estimate a 90% confidence interval for DD for a process employing the current detailed design subprocess (pre-innovation).

- Use a Monte Carlo simulation with the PPM generated earlier to evaluate what to expect for DD under the current conditions.

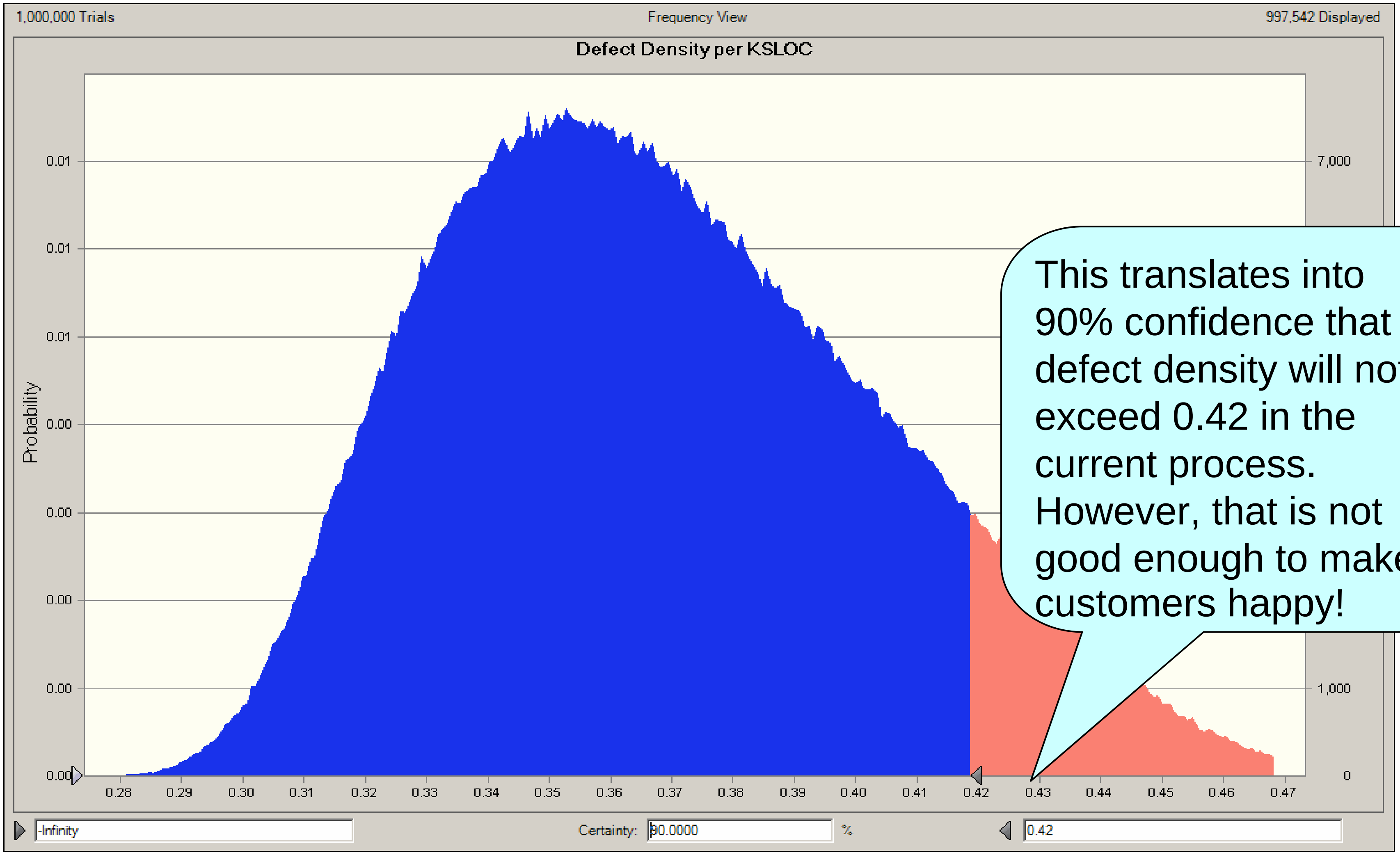
Using PPBs and PPMs to Evaluate Candidate Innovations -2

Input ranges and most likely value are specified for each factor in the PPM (reflecting the PPBs for these factors).

Defect Density	=	389	+	2.12	RV	+	5.32	DC	-	24.1	QC			
0.327124					20%			20			7			
					15%			15			2		Min	
					20%			20			7		Most Likely	
					45%			30			8		Max	

These inputs drive the simulation, resulting in a confidence interval for DD for the current detailed design subprocess.

Using PPBs and PPMs to Evaluate Candidate Innovations -3



This translates into 90% confidence that defect density will not exceed 0.42 in the current process. However, that is not good enough to make customers happy!

Using PPBs and PPMs to Evaluate Candidate Innovations -4

Step 2. Estimate a 90% confidence interval for DD for the new detailed design subprocess (simulation of the process assuming the innovation was made).

- Use a Monte Carlo simulation with the PPM generated earlier, but with a modified range for DC reflecting the behavior expected from the new detailed design subprocess.

Step 3. Repeat for other candidate innovations, if any.

Step 4. Select an innovation to further pilot.

Note: A similar analysis, perhaps performed in a more straightforward way, could also be performed in SP 1.1, especially for, but not limited to, non-trivial incremental improvements.

Using PPBs and PPMs to Evaluate Candidate Innovations -5

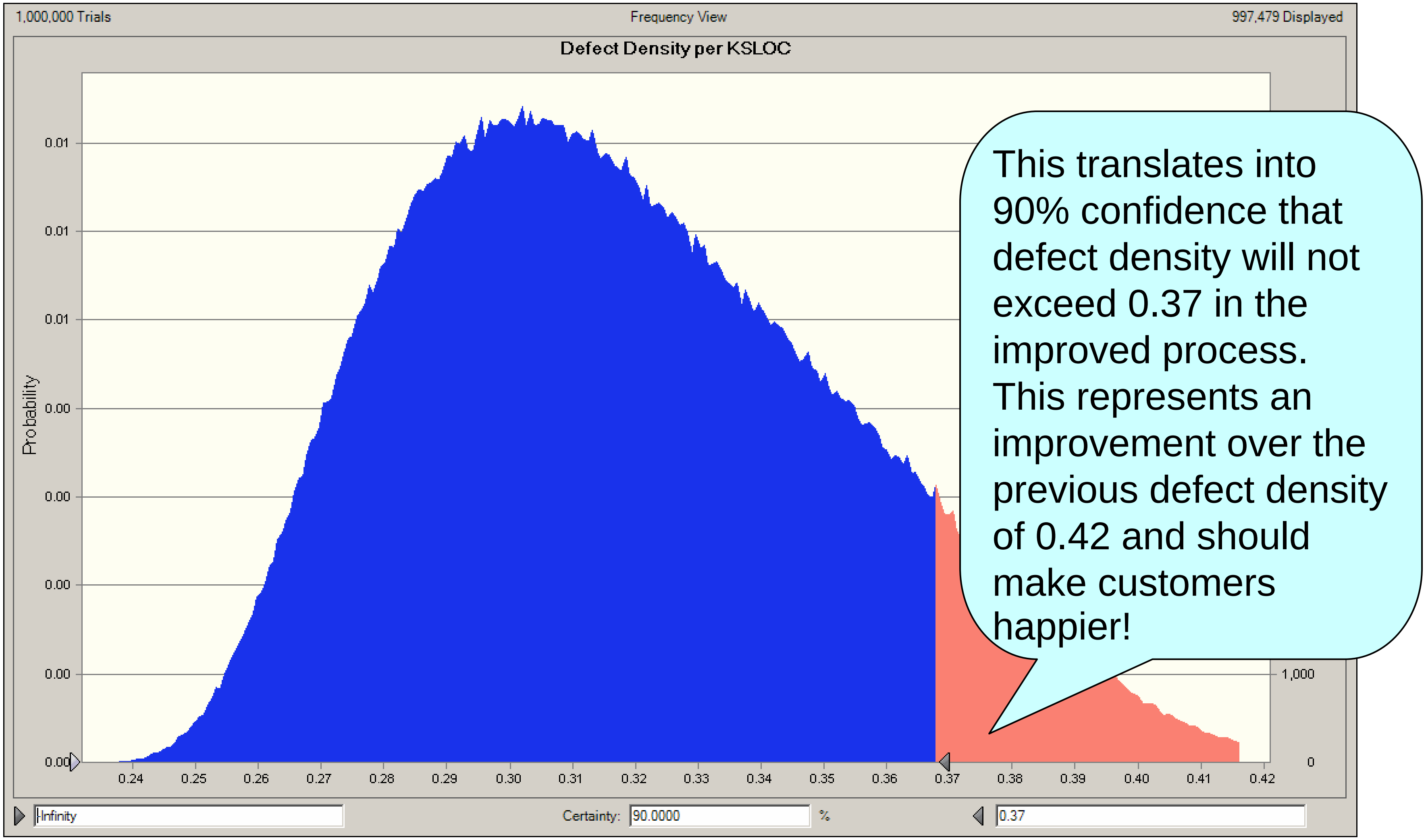
Input ranges and most likely value are specified for each factor in the PPM (reflecting the PPBs for RV and QC, but with a modified estimate for DC).

Defect Density	=	389	+	2.12	RV	+	5.32	DC	-	24.1	QC			
0.327124					20%			20			7			
					15%			7			2		Min	
					20%			10			7		Most Likely	
					45%			20			8		Max	

The candidate innovation should reduce design complexity from a range of 15-30 to this new range of 7-20

These inputs drive the simulation, resulting in a confidence interval for DD for the current detailed design subprocess.

Using PPBs and PPMs to Evaluate Candidate Innovations -6



Six Sigma/Modern Statistics Essential to OID

SG1 Select Improvements	➡	Six Sigma Big Y to Vital x semi-annual workshops; Business Goal simulation and optimization models; Benchmarking; Capability data sharing; Theory of Inventing (TRIZ) methods; Usage of performance models to identify the major opportunities for improvement with innovation; Assumption Busters; Empowered innovative thinking; Incentives for Innovation; Strong Teaming for Innovation; Various decision models such as AHP, Pugh Method, Probabilistic decision trees
SG2 Deploy Improvements	➡	Process and Design FMEA; Organizational Readiness for Change; Change Agents; Sponsors; Champions; Influence Leaders; Adoption Curve; Piloting; Risk-based deployment; Before and After comparisons with Hypothesis tests; Results compared to prediction models; Proactive mitigation of risks

High Maturity Is Management with a Navigation System

Measurement is used routinely and proactively:

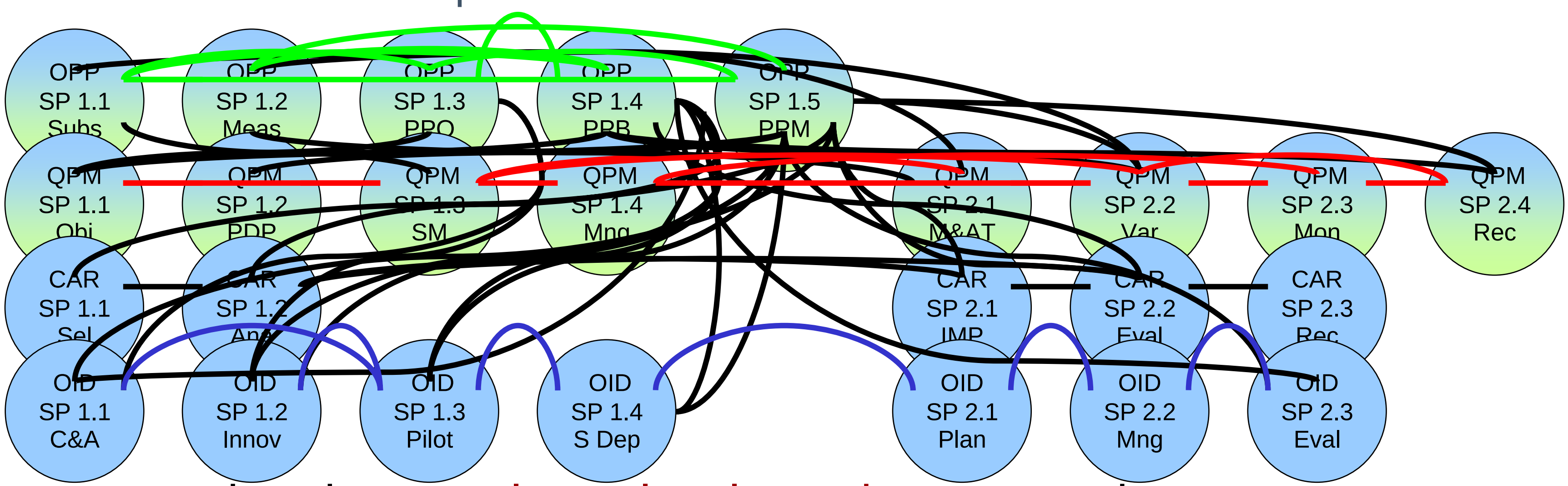
- Are we confident we know where we are, where we are going, and our performance outcomes (quantitative understanding)?
- Do we understand variation?

Use measurement results to answer the questions “Will we be successful?,” “Are our customer expectations and what we are capable of doing aligned?,” and “What if we were to do something different?”

CMMI is a Set of Interrelated Practices

Interrelationships are key to understanding levels 4 and 5.

- These interrelationships are not always obvious.
- By understanding these interrelationships, the richness of levels 4 and 5 becomes evident.
- The interrelationships become evident in the informative material – read it!



You cannot abandon your lower level practices as you become more mature—you need to evolve them and incorporate them.

Current SEI Courses Related to High Maturity

Course	Description
Understanding CMMI High Maturity Practices	CMMI level 4-5 concepts, practices, and implementation (various statistical methods are introduced)
Appraising CMMI High Maturity Organizations (proposed)	Making judgments in support of an appraisal of an organization's implementation of CMMI levels 4-5
Measuring for Performance-Driven Improvement I	Statistical methods and tools involved in analyzing data for product and process design and optimization based on the DMAIC roadmap
Measuring for Performance-Driven Improvement II	Statistical methods and tools involved in analyzing data for product and process design and optimization based on the DFSS roadmap

Conclusion

Understanding variation is the basis for management by fact and systematic improvement.

High maturity organizations use appropriate statistical and other quantitative methods to

- understand past quality and process performance
- predict future quality and process performance
- target areas for improvement and evaluate the impact of proposed improvements
- focus on innovation and how to be more competitive

The SEI is upgrading its training curriculum to help organizations further develop their knowledge and skills related to implementing and appraising CMMI high maturity practices.